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IS 9018-1 (2002): Quartz Crystal Controlled Oscillators of Assessed Quality, Part 1: Generic Specification [LITD 5: Semiconductor and Other Electronic Components and Devices]

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“Invent a New India Using Knowledge”



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Bhartṛhari—Nītiśatakam

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भाग 1 सामान्य विशिष्टि  
( पहला पुनरीक्षण )

*Indian Standard*  
QUARTZ CRYSTAL CONTROLLED  
OSCILLATORS OF ASSESSED QUALITY  
PART 1 GENERIC SPECIFICATION  
( *First Revision* )

ICS 31.140

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BUREAU OF INDIAN STANDARDS  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

## NATIONAL FOREWORD

This Indian Standard ( First Revision ) which is identical with IEC 60679-1 ( 1997 ) 'Quartz crystal controlled oscillators of assessed quality — Part 1 : Generic specification' issued by the International Electrotechnical Commission ( IEC ) was adopted by the Bureau of Indian Standards on the recommendation of Piezoelectric Devices for Frequency Control and Selection Sectional Committee and approval of the Electronics and Telecommunication Division Council.

The objective of this standard is to specify the methods of test and general requirements for quartz crystal controlled oscillators of assessed quality using either capability approval or qualification approval procedures.

This standard was first published in 1978 and was based on IEC Doc: 49 ( Sectt ) 83 'Second draft — Quartz crystal controlled oscillators' and IEC Doc: 40 ( C.O ) 107 'Draft — Quartz crystal controlled oscillators'. These IEC documents have since been published as IEC 60679 whose latest version is IEC 60679-1 ( 1997 ). The latest version of IEC 60679-1 incorporates various technical modifications. The revision of this standard, therefore, has been taken up to align it with the latest international practices.

The text of the IEC Standard has been approved as suitable for publication as Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

- Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.
- Comma ( , ) has been used as a decimal marker while in Indian Standards, the current practice is to use a point ( . ) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their place are listed below alongwith their degree of equivalence for the editions indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60050-561 ( 1991 ) International Electrotechnical Vocabulary ( IEV ) — Part 561 : Piezoelectric devices for frequency control and selection	IS 1885 ( Part 44 ) : 2001 Electrotechnical vocabulary : Part 44 Piezoelectric devices ( <i>first revision</i> )	Identical
IEC 60068-1 ( 1988 ) Environmental testing — Part 1 : General and guidance Amendment 1 ( 1992 )	a) IS 9000 ( Part 1 ) : 1988 Basic environmental testing procedures for electronic and electrical items : Part 1 General ( <i>first revision</i> ) b) IS 9001 ( Part 1 ) : 1984 Guidance for environmental testing : Part 1 General	Technically Equivalent

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60068-2-1 ( 1990 ) Environmental testing — Part 2 : Tests — Tests A : Cold Amendment 1 ( 1993 ) Amendment 2 ( 1994 )	IS 9000 ( Part 2/Sec 1 to 4 ) : 1977 Basic environmental testing procedures for electronic and electrical items : Part 2 Cold test:  Section 1 General Section 2 Cold test for non-heat dissipating items with sudden change of temperature Section 3 Cold test for non-heat dissipating items with gradual change of temperature Section 4 Cold test for heat dissipating items with gradual change of temperature	Technically Equivalent
IEC 60068-2-2 ( 1974 ) Environmental testing — Part 2 : Tests — Tests B : Dry heat Amendment 1 ( 1993 ) Amendment 2 ( 1994 )	IS 9000 ( Part 3/Sec 1 to 5 ) : 1977 Basic environmental testing procedures for electronic and electrical items: Part 3 Dry heat test:  Section 1 General Section 2 Dry heat test for non-heat dissipating items with sudden change of temperature Section 3 Dry heat test for non-heat dissipating items with gradual change of temperature Section 4 Dry heat test for heat dissipating items with sudden change of temperature Section 5 Dry heat test for heat dissipating items with gradual change of temperature	do
IEC 60068-2-3 ( 1985 ) Environmental testing — Part 2 : Tests — Test Ca: Damp heat, steady state	IS 9000 ( Part 4 ) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 4 Damp heat ( steady state )	do
IEC 60068-2-6 ( 1995 ) Environmental testing — Part 2 : Tests — Test Fc: Vibration ( sinusoidal )	IS 9000 ( Part 8 ) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 8 Vibration ( sinusoidal ) test	do

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60068-2-7 ( 1983 ) Environmental testing — Part 2 : Tests — Test Ga and guidance : Acceleration, steady state Amendment 1 ( 1986 )	a) IS 9000 ( Part 9 ) : 1984 Basic environmental testing procedures for electronic and electrical items : Part 9 Acceleration ( steady state ) b) IS 9001 ( Part 15 ) : 1979 Guidance for environmental testing : Part 15 Acceleration ( steady state ) test	Technically Equivalent
IEC 60068-2-10 ( 1988 ) Environmental testing — Part 2 : Tests — Test J and guidance : Mould growth	a) IS 9000 ( Part 10 ) : 1979 Basic environmental testing procedures for electronic and electrical items : Part 10 Mould growth test b) IS 9001 ( Part 10 ) : 1979 Guidance for environmental testing : Part 10 Mould growth test	do
IEC 60068-2-13 ( 1983 ) Environmental testing — Part 2 : Tests — Test M : Low air pressure	IS 9000 ( Part 13 ) : 1981 Basic environmental testing procedures for electronic and electrical items : Part 13 Low air pressure test	do
IEC 60068-2-14 ( 1984 ) Environmental testing — Part 2 : Tests — Test N : Change of temperature Amendment 1 ( 1986 )	IS 9000 ( Part 14/Sec 1 to 3 ) : 1988 Basic environmental testing procedures for electronic and electrical items : Part 14 Test N : Change of temperature: Section 1 Rapid change of temperature ( thermal shock ) with prescribed time of transition — Two chamber method ( <i>first revision</i> ) Section 2 Change of temperature ( temperature cycling ) with specified rate of change — One chamber method ( <i>first revision</i> ) Section 3 Rapid change of temperature ( thermal shock ) — Two fluid bath method ( <i>first revision</i> )	do
IEC 60068-2-17 ( 1994 ) Environmental testing — Part 2 : Tests — Test Q : Sealing	IS 9000 ( Part 15/Sec 1 to 9 ) : 1982 Basic environmental testing procedures for electronic and electrical items : Part 15 Sealing test:	do

International Standard	Corresponding Indian Standard	Degree of Equivalence
	<p>Section 1 General</p> <p>Section 2 Sealing of bushes, spindles and gaskets</p> <p>Section 3 Container sealing gas leakage</p> <p>Section 4 Container sealing, seepage filling liquid</p> <p>Section 5 Sealing-tracer gas ( helium ) method with mass spectrometer</p> <p>Section 6 Bomb pressure test</p> <p>Section 7 Immersion test</p> <p>Section 8 Sealing-radioactive tracer gas ( Krypton ) method</p> <p>Section 9 Sealing-test for equipment</p>	Technically Equivalent
IEC 60068-2-20 ( 1979 ) Environmental testing — Part 2 : Tests — Test T : Soldering Amendment 2 ( 1987 )	IS 9000 ( Part 18/Sec 1 to 3 ) : 1981 Basic environmental testing procedures for electronic and electrical items : Part 18 Solderability test:	do
IEC 60068-2-21 ( 1983 ) Environmental testing — Part 2 : Tests — Test U : Robustness of terminations and integral mounting devices Amendment 2 ( 1991 ) Amendment 3 ( 1992 )	<p>Section 1 Solderability of wire and tag terminations</p> <p>Section 2 Resistance of items to soldering test</p> <p>Section 3 Solderability of printed boards and metal-clad laminates</p> <p>IS 9000 ( Part 19/Sec 1 to 5 ) : 1986 Basic environmental testing procedures for electronic and electrical items : Part 19 Test U : Robustness of terminations and integral mounting devices :</p> <p>Section 1 Test Ua: Tensile ( <i>first revision</i> )</p> <p>Section 2 Test Ub: Thrust ( <i>first revision</i> )</p> <p>Section 3 Test Uc: Bending ( <i>first revision</i> )</p> <p>Section 4 Test Ud: Torsion ( <i>first revision</i> )</p> <p>Section 5 Test Ue: Torque ( <i>first revision</i> )</p>	do

International Standard	Corresponding Indian Standard	Degree of Equivalence
IEC 60068-2-27 ( 1987 ) Environmental testing — Part 2 : Tests — Test Ea and guidance : Shock	a) IS 9000 ( Part 7/Sec 1 ) : 1979 Basic environmental testing procedures for electronic and electrical items : Part 7 Impact test, Section 1 Shock b) IS 9001 ( Part 17/Sec 1 ) : 2000 Guidance for environmental testing : Part 17 Impact test, Section 1 Shock test ( first revision )	Technically Equivalent
IEC 60068-2-29 ( 1987 ) Environmental testing — Part 2 : Tests — Test Eb and guidance : Bump	a) IS 9000 ( Part 7/Sec 2 ) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Section 2 Bump b) IS 9001 ( Part 17/Sec 2 ) : 1985 Guidance for environmental testing : Part 17 Impact test, Section 2 Bump test	
IEC 60068-2-30 ( 1980 ) Environmental testing — Part 2 : Tests — Test Db and guidance : Damp heat, cyclic ( 12 + 12-hour cycle ) Amendment 1 ( 1985 )	a) IS 9000 ( Part 5/Sec 2 ) : 1981 Basic environmental testing procedures for electronic and electrical items : Part 5 Damp heat ( cyclic ) test, Section 2 12 + 12 h cycle b) IS 9001 ( Part 4 ) : 1979 Guidance for environmental testing : Part 4 Damp heat ( steady state )	do
IEC 60068-2-32 ( 1980 ) Environmental testing — Part 2 : Tests — Test Ed : Free fall Amendment 2 ( 1990 )	IS 9000 ( Part 7/Sec4 ) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Section 4 Free fall	
IEC 60068-2-45 ( 1980 ) Environmental testing — Part 2 : Tests — Test XA and guidance : Immersion in cleaning solvents Amendment 1 ( 1993 )	a) IS 9000 ( Part 20 ) : 1979 Basic environmental testing procedures for electronic and electrical items : Part 20 Resistance to cleaning solvents and permanence of markings b) IS 9001 ( Part 5 ) : 1979 Guidance for environmental testing : Part 5 Resistance to cleaning solvents and permanence of markings	do
IEC 60469-1 ( 1987 ) Pulse techniques and apparatus — Part 1 : Pulse terms and definitions	IS 14501 ( Part 1 ) : 1998 Pulse techniques and apparatus : Part 1 Pulse terms and definitions	

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
IEC 60617 Graphical symbols for diagrams	IS 12032 Graphical symbols for diagrams in the field of electrotechnology	Identical
IEC 60801-2 ( 1991 ) Electromagnetic compatibility for industrial process measurement and control equipment — Part 2 : Electrostatic discharge requirements [ since withdrawn and replaced by IEC 61000-4-2 ( 1995 ) ]	IS 14700 ( Part 4/Sec 2 ) : 1999 Electromagnetic compatibility ( EMC ) : Part 4 Testing and measurement techniques, Section 2 Electrostatic discharge immunity test	Identical to IEC 61000-4-2 ( 1995 )
IEC QC 001001 ( 1986 ) Basic rules of the IEC Quality Assessment System for Electronic Components ( IECQ ) Amendment 2 ( 1994 ) Amendment 3 ( 1995 ) ( since revised in 1998 )	ISQC 001001 : 2000 IEC Quality Assessment System for Electronic Components ( IECQ ) — Basic rules	Identical to 1998 version
IEC QC 001002 ( 1986 ) Rules of procedure of the IEC Quality Assessment System for Electronic Components ( IECQ ) Amendment 2 ( 1994 ) ( since revised in 1998 )	ISQC 001002 ( Parts 1 to 3 ) : 2000 IEC Quality Assessment System for Electronic Components ( IECQ ) — Rules of procedure : Part 1 Administration Part 2 Documentation Part 3 Approval procedures	do
ISO 31-3 ( 1992 ) Quantities and units — Part 3 : Mechanics	IS 1890 ( Part 3 ) : 1995 Quantities and units : Part 3 Mechanics	Identical
ISO 1000 ( 1992 ) SI units and recommendations for use of their multiples and of certain other units	IS 10005 : 1994 SI units and recommendations for use of their multiples and of certain other units	do
The concerned Technical Committee responsible for preparation of this standard has reviewed the provisions of the following International Publications and has decided that they are acceptable for use in conjunction with this standard:		
IEC 60027	Letter symbols to be used in electrical technology	
IEC 60068-2-36 ( 1973 )	Environmental testing — Part 2 : Tests — Test Fdb: Random vibration wide band — Reproducibility medium Amendment 1 ( 1983 )	
IEC 60068-2-52 ( 1996 )	Environmental testing — Part 2 : Tests — Test Kb: Salt mist cyclic ( sodium chloride solution )	
IEC 60068-2-58 ( 1989 )	Environmental testing — Part 2: Tests — Test Td: Solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices ( SMD )	
IEC 60679-4 ( 1997 )	Quartz crystal controlled oscillators of assessed quality — Part 4 : Sectional specification — Capability approval	
IEC 60679-5 ( 1998 )	Quartz crystal controlled oscillators of assessed quality — Part 5 : Sectional specification — Qualification approval	
IECQC 001005 ( 1996 )	Register of firms, products and services approved under the IECQ System including ISO 9000	

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard.

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## Indian Standard

# QUARTZ CRYSTAL CONTROLLED OSCILLATORS OF ASSESSED QUALITY

## PART 1 GENERIC SPECIFICATION

### 1 General

### ( *First Revision* )

#### 1.1 Scope

This part of IEC 60679 specifies the methods of test and general requirements for quartz crystal controlled oscillators of assessed quality using either capability approval or qualification approval procedures.

#### 1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60679. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 60679 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60027, *Letter symbols to be used in electrical technology*

IEC 60050-561:1991, *International Electrotechnical Vocabulary (IEV) – Part 561: Piezoelectric devices for frequency control and selection*

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*  
Amendment 1 (1992)

IEC 60068-2-1:1990, *Environmental testing – Part 2: Tests – Tests A: Cold*  
Amendment 1 (1993)  
Amendment 2 (1994)

IEC 60068-2-2:1974, *Environmental testing – Part 2: Tests – Tests B: Dry heat*  
Amendment 1 (1993)  
Amendment 2 (1994)

IEC 60068-2-3:1985, *Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state*

IEC 60068-2-6:1995, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-7:1983, *Environmental testing – Part 2: Tests – Test Ga and guidance: Acceleration, steady state*  
Amendment 1 (1986)

IEC 60068-2-10:1988, *Environmental testing – Part 2: Tests – Test J and guidance: Mould growth*

IEC 60068-2-13:1983, *Environmental testing – Part 2: Tests – Test M: Low air pressure*

IEC 60068-2-14:1984, *Environmental testing – Part 2: Tests – Test N: Change of temperature*  
Amendment 1 (1986)

IEC 60068-2-17:1994, *Environmental testing – Part 2: Tests – Test Q: Sealing*

IEC 60068-2-20:1979, *Environmental testing – Part 2: Tests – Test T: Soldering*  
Amendment 2 (1987)

IEC 60068-2-21:1983, *Environmental testing – Part 2: Tests – Test U: Robustness of terminations and integral mounting devices*  
Amendment 2 (1991)  
Amendment 3 (1992)

IEC 60068-2-27:1987, *Environmental testing – Part 2: Tests – Test Ea and guidance: Shock*

IEC 60068-2-29:1987, *Environmental testing – Part 2: Tests – Test Eb and guidance: Bump*

IEC 60068-2-30:1980, *Environmental testing – Part 2: Tests – Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle)*  
Amendment 1 (1985)

IEC 60068-2-32:1975, *Environmental testing – Part 2: Tests – Test Ed: Free fall*  
Amendment 2 (1990)

IEC 60068-2-36:1973, *Environmental testing – Part 2: Tests – Test Fdb: Random vibration wide band – Reproducibility medium*  
Amendment 1 (1983)

IEC 60068-2-45:1980, *Environmental testing – Part 2: Tests – Test XA and guidance: Immersion in cleaning solvents*  
Amendment 1 (1993)

IEC 60068-2-52:1996, *Environmental testing – Part 2: Tests – Test Kb: Salt mist, cyclic (sodium chloride solution)*

IEC 60068-2-58:1989, *Environmental testing – Part 2: Tests – Test Td: Solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)*

IEC 60469-1:1987, *Pulse techniques and apparatus – Part 1: Pulse terms and definitions*

IEC 60617, *Graphical symbols for diagrams*

IEC 60679-4,— *Quartz crystal controlled oscillators of assessed quality – Part 4: Sectional specification – Capability approval 1)*

IEC 60679-5,— *Quartz crystal controlled oscillators of assessed quality – Part 5: Sectional specification – Qualification approval 1)*

IEC 60801-2: 1991, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 2: Electrostatic discharge requirements*

IEC QC 001001: 1986, *Basic rules of the IEC Quality Assessment System for Electronic Components (IECQ)*  
Amendment 2 (1994)  
Amendment 3 (1995)

IEC QC 001002: 1986, *Rules of procedure of the IEC Quality Assessment System for Electronic Components (IECQ)*  
Amendment 2 (1994)

IEC QC 001005: 1996, *Register of firms, products and services approved under the IECQ System, including ISO 9000*

ISO 31-3: 1992, *Quantities and units – Part 3: Mechanics*

ISO 1000: 1992, *SI units and recommendations for use of their multiples and of certain other units*

### 1.3 Order of precedence

Where any discrepancies occur for any reason, documents shall rank in the following order of precedence:

- detail specification;
- sectional specification;
- generic specification;
- any other international documents (for example of the IEC) to which reference is made.

The same order of precedence shall apply to equivalent national documents.

## 2 Terminology and general requirements

### 2.1 General

Units, graphical symbols, letter symbols and terminology shall, wherever possible, be taken from the following standards:

IEC 60027  
IEC 60050-561  
IEC 60469-1  
IEC 60617  
ISO 1000

### 2.2 Definitions

For the purpose of this part of IEC 60679, the following definitions are applicable:

#### 2.2.1

##### **simple packaged crystal oscillator (SPXO)**

a crystal controlled oscillator having no means of temperature control or compensation, exhibiting a frequency/temperature characteristic determined substantially by the piezoelectric resonator employed [IEV 561-04-01]

## 2.2.2

### **overtone quartz crystal controlled oscillator**

an oscillator designed to operate with the controlling piezoelectric resonator functioning in a specified mechanical overtone order of vibration [IEV 561-04-02]

## 2.2.3

### **crystal cut**

the orientation of the crystal element with respect to the crystallographic axes of the crystal

NOTE – This definition is included as it may be desirable to specify the cut (and hence the general form of the frequency/temperature performance) of a crystal unit used in an oscillator application. The choice of the crystal cut will imply certain attributes of the oscillator which may not otherwise appear in the detail specification.

## 2.2.4

### **voltage controlled crystal oscillator (VCXO)**

a crystal controlled oscillator, the frequency of which can be deviated or modulated according to a specified relation, by application of a control voltage [IEV 561-04-03]

## 2.2.5

### **temperature compensated crystal oscillator (TCXO)**

a crystal controlled oscillator whose frequency deviation due to temperature is reduced by means of a compensation system, incorporated in the device [IEV 561-04-04]

## 2.2.6

### **oven controlled crystal oscillator (OCXO)**

a crystal controlled oscillator in which at least the piezoelectric resonator is temperature controlled [IEV 561-04-05]

NOTE – This mode of operation ensures that the oscillator frequency will remain sensibly constant over the operating temperature range of the OCXO, therefore independent of the frequency/temperature characteristic of the crystal unit.

## 2.2.7

### **nominal frequency**

the frequency used to identify the crystal controlled oscillator [IEV 561-04-06]

## 2.2.8

### **frequency tolerance**

the maximum permissible deviation of the oscillator frequency from a specified nominal value when operating under specified conditions [IEV 561-04-07]

NOTE – Frequency tolerances are often assigned separately to specified ambient effects, namely electrical, mechanical and environmental. When this approach is used, it is necessary to define the values of other operating parameters as well as the range of the specified variable, that is:

- deviation from the frequency at the specified reference temperature due to operation over the specified temperature range, other conditions remaining constant;
- deviation from the frequency at the specified supply voltage due to supply voltage changes over the specified range, other conditions remaining constant;
- deviation from the initial frequency due to ageing, other conditions remaining constant;
- deviation from the frequency with specified load conditions due to changes in load impedance over the specified range, other conditions remaining constant.

In some cases, an overall frequency tolerance may be specified, due to any/all combinations of operating parameters, during a specified lifetime.

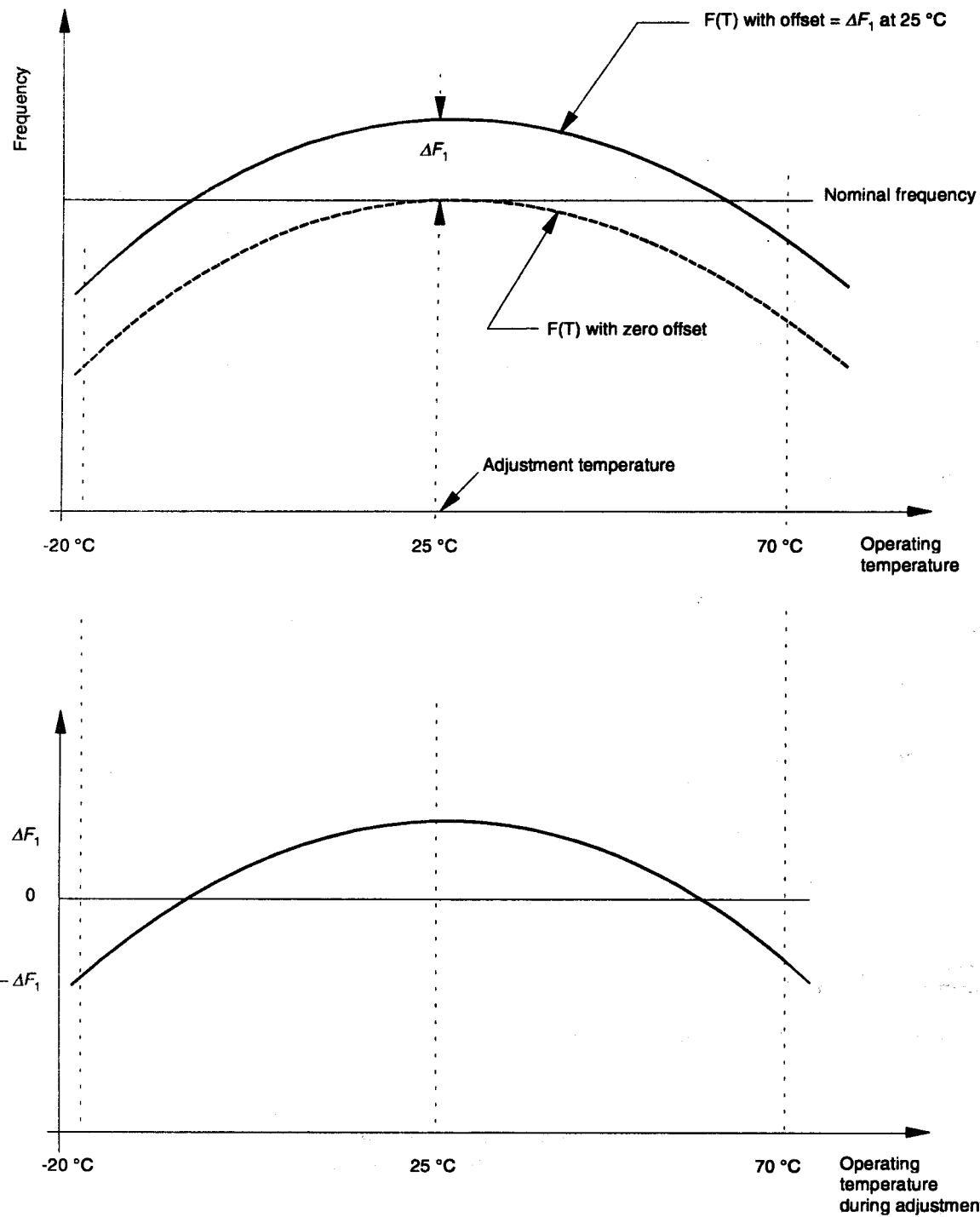
## 2.2.9

### **frequency offset**

the frequency difference, positive or negative, which should be added to the specified nominal frequency of the oscillator, when adjusting the oscillator frequency under a particular set of operating conditions in order to minimize its deviation from nominal frequency over the specified range of operating conditions [IEV 561-04-08]

**Example:**

In order to minimize the frequency deviation from nominal over the entire temperature range, a frequency offset may be specified for adjustment at the reference temperature (see figure 1).



**Figure 1 – Example of the use of frequency offset**

**2.2.10**

**adjustment frequency**

the frequency to which an oscillator must be adjusted, under a particular combination of operating conditions, in order to meet the frequency tolerance specification over the specified range of operating conditions, i.e. adjustment frequency = nominal frequency + frequency offset [IEV 561-04-09]

**2.2.11**

**frequency adjustment range**

the range over which the oscillator frequency may be varied by means of some variable element, for the purpose of:

- a) setting the frequency to a particular value, or
- b) to correct the oscillator frequency to a prescribed value after deviation due to ageing, or other changed conditions. [IEV 561-04-10]

**2.2.12**

**storage temperature range**

the minimum and maximum temperatures as measured on the enclosure at which the crystal controlled oscillator may be stored without deterioration or damage to its performance

**2.2.13**

**operating temperature range**

the range of temperature over which the oscillator will function, maintaining frequency and other output signal characteristics within specified tolerances [IEV 561-04-11]

**2.2.14**

**operable temperature range**

the range of temperature over which the oscillator will continue to provide an output signal, though not necessarily within the specified tolerances of frequency, level, waveform, etc. [IEV 561-04-12]

**2.2.15**

**reference temperature**

the temperature at which certain oscillator performance parameters are measured, normally  $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$

**2.2.16**

**reference point temperature**

the temperature measured at a specific reference point relative to the oscillator

**2.2.17**

**thermal transient frequency stability**

the oscillator frequency time response when ambient temperature is changed from one specific temperature to another with a specific rate

**2.2.18**

**stabilization time**

the time, measured from the initial application of power, required for a crystal controlled oscillator to stabilize its operation within specified limits [IEV 561-04-13]

**2.2.19**

**frequency/voltage coefficient**

the fractional change in output frequency resulting from an incremental change in supply voltage, other parameters remaining unchanged [IEV 561-04-14]

NOTE – In the case of OCXOs, a considerable time may elapse before the full effect of a supply voltage change is observed, as the temperature of the oven may drift gradually to a new value following the voltage perturbation.

## 2.2.20

### frequency/load coefficient

the fractional change in output frequency resulting from an incremental change in electrical load impedance, other parameters remaining unchanged [IEV 561-04-15]

## 2.2.21

### long-term frequency stability (frequency ageing)

the relationship between oscillator frequency and time. This long-term frequency drift is caused by secular changes in the crystal unit and/or other elements of the oscillator circuit, and should be expressed as fractional change in mean frequency per specified time interval.

## 2.2.22

### short-term frequency stability

the random fluctuations of the frequency of an oscillator over short periods of time [IEV 561-04-16]

## 2.2.23

### Allan variance of fractional frequency fluctuation

An unbiased estimate of the preferred definition in the time domain of the short-term stability characteristic of the oscillator output frequency:

$$\sigma_y^2(\tau) \equiv \frac{1}{M-1} \sum_{k=1}^{M-1} \frac{(Y_{k+1} - Y_k)^2}{2}$$

where

$Y_k$  are the average fractional frequency fluctuations obtained sequentially, with no systematic dead time between measurements;

$\tau$  is the sample time over which measurement is averaged;

$M$  is the number of measurements.

The confidence on the estimate improves as  $M$  increases.

## 2.2.24

### RMS fractional frequency fluctuation

a measure in the time domain of the short-term frequency stability of an oscillator, based on the statistical properties of a number of frequency measurements, each representing an average of the frequency over the specified sampling interval  $\tau$ . The preferred measure of fractional frequency fluctuation is:

$$\frac{\Delta F}{F_0}(\tau)_{\text{rms}} = \left[ \frac{1}{2(M-1)} \sum_{k=1}^{M-1} (Y_{k+1} - Y_k)^2 \right]^{1/2} = [\sigma_y^2(\tau)]^{1/2}$$

## 2.2.25

### phase noise

the frequency-domain measure of the short-term frequency stability of an oscillator, normally expressed as the power spectral density of the phase fluctuations,  $S_\phi(f)$ , where the phase fluctuation function is  $\phi(t) = 2\pi F t - 2\pi F_0 t$ . The spectral density of phase fluctuation can be directly related to the spectral density of frequency fluctuation by:

$$S_\phi(f) = \left( \frac{F_0}{f} \right)^2 S_y(f) \text{ radian}^2 \text{ per hertz}$$

where

$F$  is the oscillator frequency;

$F_0$  is the average oscillator frequency;

$f$  is the Fourier frequency.

**2.2.26**

**spectral purity**

the measure of frequency stability in the frequency domain usually represented as the signal side noise power spectrum expressed in decibels relative to total signal power, per hertz bandwidth. It includes non-deterministic noise power, harmonic distortion components and spurious single frequency interferences.

**2.2.27**

**incidental frequency modulation**

the optional measure of frequency stability in the frequency domain. Incidental frequency modulation is best described in terms of the spectrum of the resultant base-band signal obtained by applying the oscillator signal to an ideal discriminator circuit of specified characteristics. If the detection bandwidth is adequately specified, the incidental frequency modulation may be expressed as a fractional proportion of the output frequency (for example  $2 \times 10^{-8}$  r.m.s. in a 10 kHz band).

**2.2.28**

**amplitude modulation distortion**

the non-linear distortion in which the relative magnitudes of the spectral components of the modulating signal waveform are modified. It is also commonly known as frequency distortion, amplitude distortion and amplitude/frequency distortion.

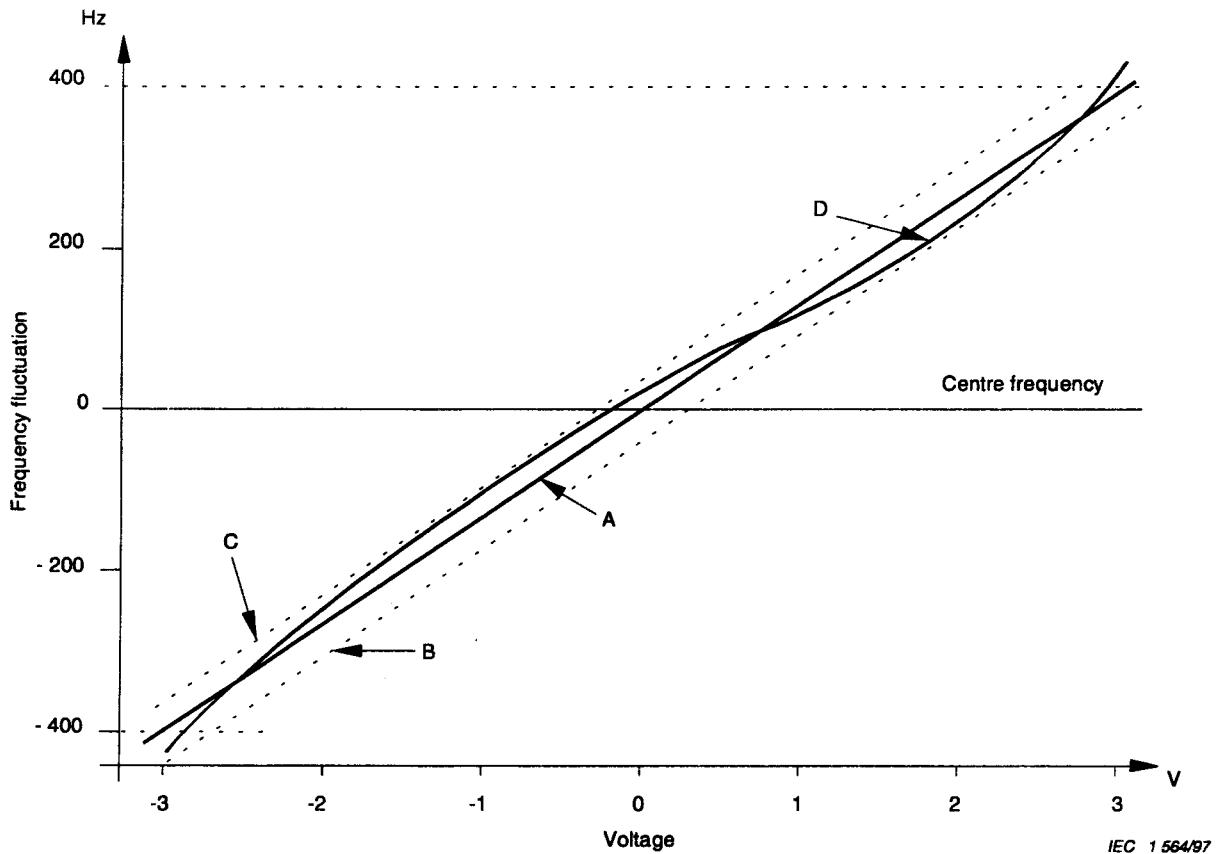
**2.2.29**

**linearity of frequency modulation deviation**

measure of the transfer characteristic of a modulation system as compared to an ideal (straight line) function, usually expressed as an allowable non-linearity in per cent of the specified full range deviation. Modulation linearity can also be expressed in terms of the permissible distortion of base-band signals produced by the modulation device (for example, intermodulation and harmonic distortion products not to exceed -40 dB relative to the total modulating signal power).

**Example:**

Figure 2 is a plot of the output frequency of a typical modulated oscillator specified to have a modulation characteristic of 133,3 Hz/V over a range of  $\pm 3$  V, with an allowed non-linearity of  $\pm 5\%$ . Curve D is the actual characteristic compared with the ideal (curve A) and the limits (curves B and C).



**Figure 2 – Typical frequency fluctuation characteristics**

**2.2.30**

**harmonic distortion**

the non-linear distortion characterized by the generation of undesired spectral components harmonically related to the desired signal frequency. Each harmonic component is usually expressed as a power ratio (in decibels) relative to the output power of the desired signal.

**2.2.31**

**spurious oscillations**

the discrete frequency spectral components, non-harmonically related to the desired output frequency, appearing at the output terminal of an oscillator. These components may appear as symmetrical sidebands or as signal spectral components, depending upon the mode of generation. Spurious components in the output spectrum are usually expressed as a power ratio (in decibels) with respect to the output signal power.

**2.2.32**

**pulse duration**

the duration between pulse start time and pulse stop time (see figure 3) [IEC 60469-1]

### 2.2.33

#### rise time

the time interval required for the leading edge of a waveform to change between two defined levels. These levels may be two logic levels  $V_{OL}$  and  $V_{OH}$  or 10 % to 90 % of its maximum amplitude ( $V_{HI} - V_{LO}$ ), or any other ratio defined in the detail specification (see figure 3).

where

$V_{OL}$  is the low level output voltage;

$V_{OH}$  is the high level output voltage;

$V_{HI}$  is the upper flat voltage of the pulse waveform;

$V_{LO}$  is the low flat voltage of the pulse waveform.

### 2.2.34

#### decay (or fall) time

the time interval required for the trailing edge of a waveform to change between two defined levels. These levels may be two logic levels  $V_{OH}$  and  $V_{OL}$  or 90 % to 10 % of its maximum amplitude ( $V_{HI} - V_{LO}$ ), or any other ratio as defined in the detail specification (see figure 3).

### 2.2.35

#### tri-state output

an output stage which may be enabled or disabled by the application of an input control signal. In the disable mode the output impedance of the gate is set to a high level permitting the application of test signals to following stages.

### 2.2.36

#### symmetry (mark/space ratio or duty cycle)

the ratio between the time ( $t_1$ ), in which the output voltage is above a specified level, and the time ( $t_2$ ), in which the output voltage is below the specified level, in percent of the duration of the full signal period. The specified level may be the arithmetic mean between levels  $V_{OL}$  and  $V_{OH}$ , or 50 % of the peak-to-peak amplitude (see figure 3).

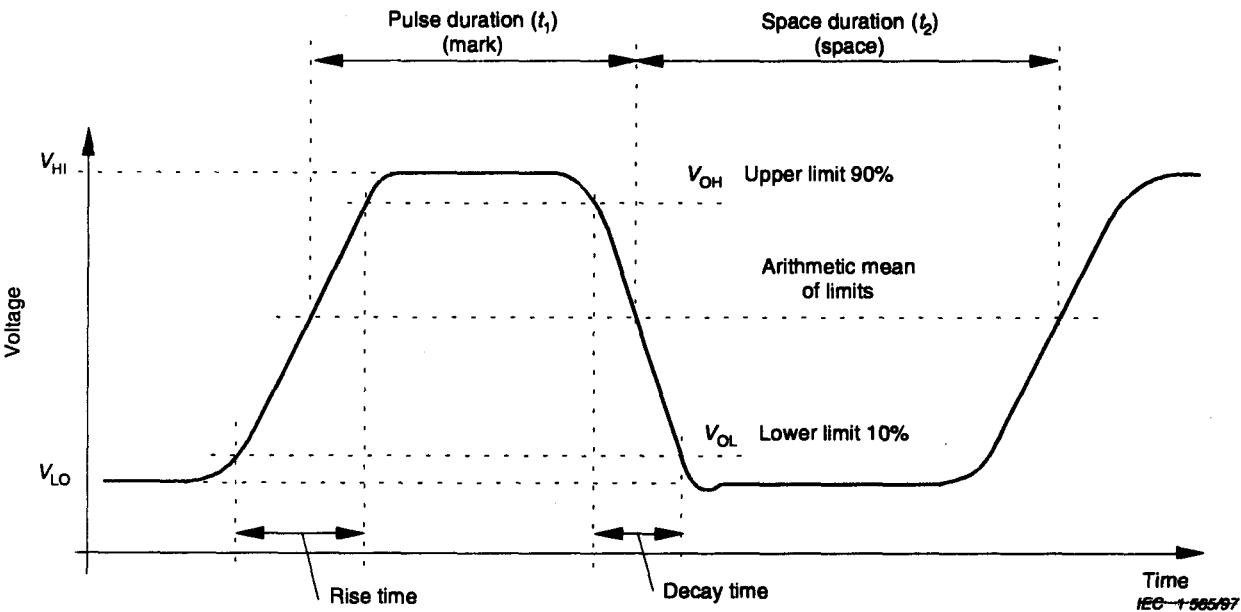


Figure 3 – Characteristics of an output waveform

The ratio is expressed as:

$$\frac{100 t_1}{t_1 + t_2} : \frac{100 t_2}{t_1 + t_2}$$

### 2.2.37

#### **retrace characteristics**

the ability of an oscillator to return, after a specified time period, to a previously stabilised frequency, following a period in the energised condition

### 2.2.38

#### **start-up time**

the time difference  $t_{SU}$  between the application of the supply voltage to the oscillator and the time when the r.f. output signal of desired frequency controlled by the quartz resonator fulfils specific conditions which are given below

##### a) Quasi-sinusoidal waveforms

The signal envelope is 90 % of the steady-state peak-to-peak amplitude (see figure 15).

##### b) Pulse waveforms

The output pulse sequence is periodical near the steady-state frequency while its low level  $V_{LO}$  remains below  $V_{OL}$  and its high level  $V_{HI}$  exceeds  $V_{OH}$  permanently, where  $V_{OH}$  and  $V_{OL}$  are defined by the applicable logic family.

#### **Precaution**

The output signal may show spurious oscillations prior to the appearance of the steady-state signal.

### 2.3 Preferred values for ratings and characteristics

Values should be preferably chosen from the following paragraphs, unless otherwise stated in the detail specification.

#### 2.3.1 Climatic category (40/085/56)

For requirements where the operating temperature range of the quartz crystal controlled oscillator is greater than  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ , a climatic category consistent with the operating temperature range shall be specified.

#### 2.3.2 Bump severity

$(4\ 000 \pm 10)$  bumps at  $400\ \text{m/s}^2$  peak acceleration in each direction along three mutually perpendicular axes (see 4.6.6). Pulse duration: 6 ms.

### 2.3.3 Vibration severity

#### Sinusoidal

10 Hz to 55 Hz  
0,75 mm displacement amplitude  
(peak value)

30 min in each of three mutually  
perpendicular axes at 1 octave/min  
(see 4.6.7)

55 Hz to 500 Hz  
or 55 Hz to 2 000 Hz  
100 m/s<sup>2</sup> acceleration amplitude  
(peak value)

10 Hz to 55 Hz  
1,5 mm displacement amplitude  
(peak value)

30 min in each of three mutually  
perpendicular axes at 1 octave/min  
(see 4.6.7)

55 Hz to 2 000 Hz  
200 m/s<sup>2</sup> acceleration amplitude  
(peak value)

#### Random

(19,2 m/s<sup>2</sup>)<sup>2</sup>/Hz between 20 Hz  
and 2 000 Hz

30 min in each of three mutually  
perpendicular axes at 1 octave/min  
(see 4.6.7)

196 m/s<sup>2</sup> acceleration

or

(48 m/s<sup>2</sup>)<sup>2</sup>/Hz between 20 Hz  
and 2 000 Hz

314 m/s<sup>2</sup> acceleration

### 2.3.4 Shock severity

1 000 m/s<sup>2</sup> peak acceleration for 6 ms duration; three shocks in each direction along three  
mutually perpendicular axes (see 4.6.8), half-sine pulse, unless otherwise stated in the detail  
specification.

### 2.3.5 Leak rate

10<sup>-1</sup> Pa cm<sup>3</sup>/s (10<sup>-6</sup> bar cm<sup>3</sup>/s)

10<sup>-3</sup> Pa cm<sup>3</sup>/s (10<sup>-8</sup> bar cm<sup>3</sup>/s)

### 2.4 Marking

**2.4.1** The quartz crystal controlled oscillator shall be clearly and durably marked (see 4.6.21)  
with items a) to g) below, and with as many of the remaining items as considered necessary:

- a) type designation as defined in the detail specification;
- b) nominal frequency in kilohertz or megahertz;
- c) year and week of manufacture;
- d) mark of conformity (unless a certificate of conformity is used);
- e) factory identification code;
- f) manufacturer's name or trade mark;
- g) terminal identification;
- h) designation of electrical connections;
- j) power supply voltage and polarity (if applicable);
- k) serial number (if applicable).

Where the available surface area of miniature quartz crystal controlled oscillators imposes  
practical limits in the amount of marking, instructions on the marking to be applied shall be  
given in the detail specification.

**2.4.2** The primary packaging containing the quartz crystal controlled oscillator(s) shall be clearly marked with the information listed in 2.4.1 except item g) and electrostatic sensitive device (ESD) identification, where necessary.

### **3 Quality assessment procedures**

Two methods are available for the approval of quartz crystal controlled oscillators of assessed quality. They are qualification approval and capability approval.

#### **3.1 Primary stage of manufacture**

The primary stage of manufacture for a quartz crystal controlled oscillator in accordance with 11.1.1 of IEC QC 001002 shall be as follows:

- a) for oscillators incorporating a sealed crystal unit:
  - the assembly of the quartz crystal controlled oscillator;
- b) for oscillators incorporating an unencapsulated crystal unit:
  - the final surface finishing of the crystal element in addition to the assembly of the oscillator.

NOTE – The final surface finishing of the crystal element could be any of the following operations: lapping; polishing; etching; cleaning, in the case of polished plates.

#### **3.2 Structurally similar components**

The grouping of structurally similar crystal controlled oscillators for the purpose of qualification approval, capability approval and quality conformance inspection shall be prescribed in the relevant sectional specification.

#### **3.3 Subcontracting**

These procedures shall be in accordance with 11.1.2 of IEC QC 001002.

There shall be no subcontracting after the assembly of the crystal to the electronic circuit, except in the case of sealed crystal units, where the sealing of the final enclosure of the oscillator may be permitted.

#### **3.4 Incorporated components**

Where the final component contains components of a kind covered by a generic specification in the IEC series, these shall be produced using the normal IEC release procedures.

Where the contained components are not produced to an IEC detail specification, the approved manufacturer's chief inspector shall verify their quality by the use of

- a procurement specification covering all aspects necessary to ensure their satisfactory performance as part of the final product,
- an adequate approval test programme maintaining a record of results,
- sufficient goods inward inspection procedures to ensure continued satisfactory performance of the final product.

#### **3.5 Manufacturer's approval**

To obtain manufacturer's approval the manufacturer shall meet the requirements of 10.2 of IEC QC 001002.

### **3.6 Approval procedures**

#### **3.6.1 General**

To qualify a quartz crystal controlled oscillator, either capability approval or qualification approval procedures may be used. These procedures conform to those stated in IEC QC 001001 and IEC QC 001002.

#### **3.6.2 Capability approval**

Capability approval is appropriate when structurally similar quartz crystal controlled oscillators based on common design rules, are fabricated by a group of common processes.

Under capability approval, detail specifications fall into the following three categories.

**a) Capability qualifying components (CQCs)**

A detail specification shall be prepared for each CQC as agreed with the NSI. It shall identify the purpose of the CQC and include all relevant stress levels and test limits.

**b) Standard catalogue items**

When a component covered by the capability approval procedure is intended to be offered as a standard catalogue item, a detail specification complying with the blank detail specification shall be written. Such specifications shall be registered by the IECQ and the component may be listed in IEC QC 001005.

**c) Custom built quartz controlled oscillators.**

The contents of the detail specification shall be by agreement between the manufacturer and the customer in accordance with 11.7.4.2 of IEC QC 001002.

Further information on detail specifications is contained in the sectional specification IEC 60679-4.

The product and capability qualifying components (CQCs) are tested in combination and approval given to a manufacturing facility on the basis of validated design rules, processes and quality control procedures. Further information is given in 3.7 and in the sectional specification IEC 60679-4.

#### **3.6.3 Qualification approval**

Qualification approval is appropriate for components manufactured to a standard design and established production process and conforming to a published detail specification.

The programme of tests defined in the detail specification for the appropriate assessment and severity level applies directly to the quartz crystal controlled oscillator to be qualified, as prescribed in 3.8 and the sectional specification IEC 60679-5.

### **3.7 Procedures for capability approval**

#### **3.7.1 General**

The procedures for capability approval shall be in accordance with IEC QC 001002.

#### **3.7.2 Eligibility for capability approval**

The manufacturer shall comply with the requirements of 11.1 of IEC QC 001002 and the primary stage of manufacture as defined in 3.1 of this generic specification.

### **3.7.3 Application for capability approval**

In order to obtain capability approval the manufacturer shall apply the rules of procedure given in 11.7 of IEC QC 001002.

### **3.7.4 Granting of capability approval**

Capability approval shall be granted when the procedures in accordance with 11.7 of IEC QC 001002 have been successfully completed.

### **3.7.5 Capability manual**

The contents of the capability manual shall be in accordance with the requirements of the sectional specification.

The NSI shall treat the capability manual as a confidential document. The manufacturer may, if he so wishes, disclose part or all of it to a third party.

## **3.8 Procedures for qualification approval**

### **3.8.1 General**

The procedures for qualification approval shall be in accordance with IEC QC 001002.

### **3.8.2 Eligibility for qualification approval**

The manufacturer shall comply with the requirements of 11.1 of IEC QC 001002 and the primary stage of manufacture as defined in 3.1 of this generic specification.

### **3.8.3 Application for qualification approval**

In order to obtain qualification approval the manufacturer shall apply the procedures given in 11.2 of IEC QC 001002.

### **3.8.4 Granting of qualification approval**

Qualification approval shall be granted when the procedures in accordance with 11.3 of IEC QC 001002 have been successfully completed.

### **3.8.5 Quality conformance inspection**

The blank detail specification associated with the sectional specification shall prescribe the test schedule for quality conformance inspection.

## **3.9 Test procedures**

The test procedures to be used shall be selected from this generic specification. If any required test is not included, then it shall be defined in the detail specification.

## **3.10 Screening requirements**

Where screening is required by the customer for quartz crystal controlled oscillators, this shall be specified in the detail specification.

### **3.11 Rework and repair work**

#### **3.11.1 Rework**

Rework is the rectification of processing errors and shall not be carried out if prohibited by the sectional specification. The sectional specification shall state if there is a restriction on the number of occasions that rework may take place on a specific component.

All rework shall be carried out prior to the formation of the inspection lot offered for inspection to the requirements of the detail specification.

Such rework procedures shall be fully described in the relevant documentation produced by the manufacturer and shall be carried out under the direct control of the chief inspector. Subcontracting of rework is not permitted.

#### **3.11.2 Repair work**

Repair work is the correction of defects in a component after release to the customer.

Components that have been repaired can no longer be considered as representative of the manufacturer's production and may not be released under the IECQ system.

### **3.12 Certified test records**

The requirements of clause 14 of IEC QC 001002 shall apply. When certified test records (CTR) are prescribed in the sectional specification for qualification approval and are requested by the customer, the results of the specified tests shall be summarized.

### **3.13 Validity of release**

Quartz crystal controlled oscillators held for a period exceeding two years following acceptance inspection shall be reinspected for the electrical tests detailed in 4.5.4 and 4.5.17, with a sample tested as described in 4.6.3.1, prior to release.

### **3.14 Release for delivery**

Quartz crystal controlled oscillators shall be released in accordance with 12.5 of IEC QC 001002.

### **3.15 Unchecked parameters**

Only those parameters of a component which have been specified in a detail specification and which were subject to testing, can be assumed to be within the specified limits. It should not be assumed that any parameter not specified will remain unchanged from one component to another. Should it be necessary for further parameters to be controlled, then a new, more extensive, detail specification should be used. The additional test method(s) shall be fully described and appropriate limits, AQLs and inspection levels specified.

## **4 Test and measurement procedures**

### **4.1 General**

The test and measurement procedures shall be carried out in accordance with the relevant detail specification.

## 4.2 Test and measurement conditions

### 4.2.1 Standard conditions for testing

Unless otherwise specified, all tests shall be carried out under the standard atmospheric conditions for testing as specified in 5.3 of IEC 60068-1.

Temperature	15 °C to 35 °C;
Relative humidity	45 % to 75 %
Air pressure	86 kPa to 106 kPa (860 mbar to 1 060 mbar)

In case of dispute, the referee conditions are the following:

Temperature	25 °C ± 2 °C
Relative humidity	48 % to 52 %
Air pressure	86 kPa to 106 kPa (860 mbar to 1 060 mbar)

Before measurements are made, the quartz crystal controlled oscillators shall be stored at the measuring temperature for a time sufficient to allow the quartz crystal controlled oscillator to reach thermal equilibrium. Controlled recovery conditions and standard conditions for assisted drying are given in 5.4 and 5.5 of IEC 60068-1.

The ambient temperature during the measurements shall be recorded and stated in the test report.

### 4.2.2 Equilibrium conditions

All electrical tests shall be conducted under equilibrium conditions, unless otherwise specified. When test conditions cause a significant change with time of the characteristic being measured, means of compensation for such effects shall be specified, for example the period of time that the oscillator shall be maintained at specified test conditions before making a measurement.

### 4.2.3 Air flow conditions for temperature tests

When devices are to be measured at temperatures other than 25 °C ± 2 °C, they shall be subjected to adequate forced air circulation to ensure close temperature control.

If heat loss due to forced air circulation affects the performance of the oscillator, still air conditions shall be simulated by enclosing the oscillator in a draught shield consisting of a thermally conducting box, having internal dimensions such that a 20 mm ± 5 mm clearance is maintained from all surfaces. The temperature at which measurements should be taken under these conditions is the reference point temperature on the surface of the draught shield.

If a draught shield is necessary, it shall be used for both high and low temperature tests.

### 4.2.4 Power supplies

DC power sources used in the testing of crystal controlled oscillators shall not have a ripple content large enough to effect the desired accuracy of measurement; a.c. power sources shall be transient free. When the ripple and/or the transient content of the power sources are critical to the measurement being performed, their effects shall be fully defined in the detail specification.

#### **4.2.5 Precision of measurement**

The limits given in the detail specification are true values. Measurement inaccuracies shall be taken into account when evaluating the results. Precautions should be taken to reduce measurement errors to a minimum.

#### **4.2.6 Precautions**

##### **4.2.6.1 Measurements**

The measurement circuits shown for specified electrical tests are the preferred circuits. Due allowance shall be made for any loading effects in cases where the measuring apparatus modifies the characteristics being examined.

##### **4.2.6.2 Electrostatic sensitive devices**

Where the component is identified as electrostatic sensitive, precautions shall be taken to prevent damage from electrostatic charge both before, during, and after test (see IEC 60801-2).

#### **4.2.7 Alternative test methods**

Measurements shall preferably be carried out using the methods specified. Any other method giving equivalent results may be used, except in case of dispute.

NOTE – "Equivalent" means that the value of the characteristic established by such other methods falls within the specified limits when measured by the specified method.

### **4.3 Visual inspection**

Unless otherwise specified, external visual examination shall be performed under normal factory lighting and visual conditions.

#### **4.3.1 Visual test A**

The quartz crystal controlled oscillator shall be visually examined to ensure that the condition, workmanship and finish are satisfactory. The marking shall be legible.

#### **4.3.2 Visual test B**

The quartz crystal controlled oscillator shall be visually examined under  $\times 10$  magnification. There shall be no cracks in the glass or damage to the terminations. Minute flaking around the further edge of a meniscus shall not be considered a crack.

#### **4.3.3 Visual test C**

The quartz crystal controlled oscillator shall be visually examined. There shall be no corrosion or other deterioration likely to impair satisfactory operation. The marking shall be legible.

### **4.4 Dimensions and gauging procedures**

#### **4.4.1 Dimensions – Test A**

The dimensions, spacing, and alignment of the terminations shall be checked and shall comply with the specified values.

#### **4.4.2 Dimensions – Test B**

The dimensions shall be measured and shall comply with the specified values.

## 4.5 Electrical test procedures

### 4.5.1 Insulation resistance

A maximum voltage of 20 V, unless otherwise stated in the detail specification, shall be applied to the specified test points using the test circuit shown in figure 4a. The resulting current shall be measured. It shall be less than the specified maximum value.

Alternatively, the resistance shall be directly measured with an ohmmeter (see figure 4b). It shall be greater than the minimum specified.

Precautions shall be taken to ensure that measurements are made across the specified points with an applied voltage of the correct polarity and not exceeding the specified value. Failure to observe any of these conditions may result in damage to the device under test.

After the test, measurements shall be made to ensure that the oscillator is still functional.

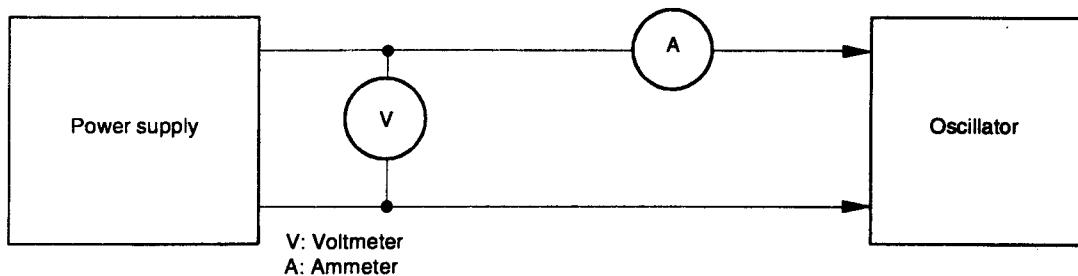


Figure 4a – Voltage-current method

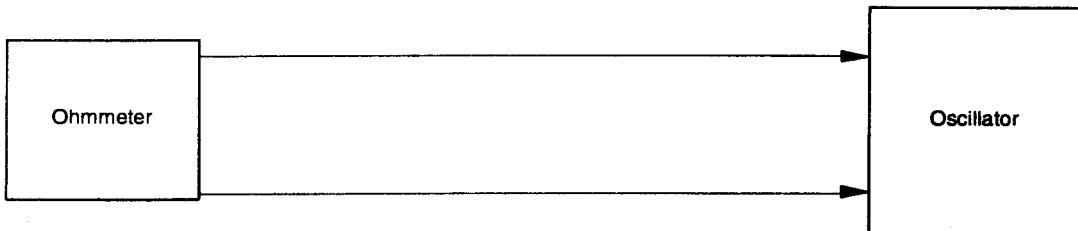


Figure 4 – Test circuits for insulation resistance measurements

### 4.5.2 Voltage proof

The specified voltage shall be applied only across the designated terminals, using the test circuit shown in figure 5, after any specified preconditioning procedures have been applied. The source resistance and maximum permissible current flow shall be stated in the detail specification.

There shall be no arcing or other evidence of electrical breakdown.

After the test, measurements shall be made to ensure that the oscillator is still functional.

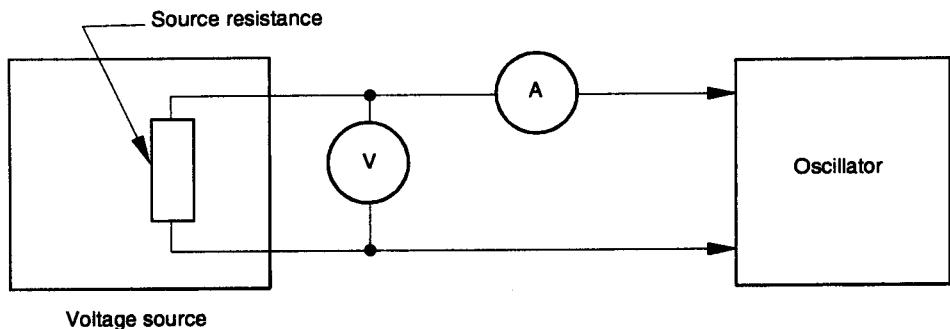


Figure 5 – Test circuit for voltage proof test

#### 4.5.3 Input power

##### 4.5.3.1 Oscillator input power

The oscillator shall be connected to the power supply and specified load as shown in figure 6. The specified voltage shall be applied and allowed to stabilize for the specified time. Measurements of the voltage and current shall be made at the reference temperature, unless otherwise stated in the detail specification. The input power shall be calculated using these measurements.

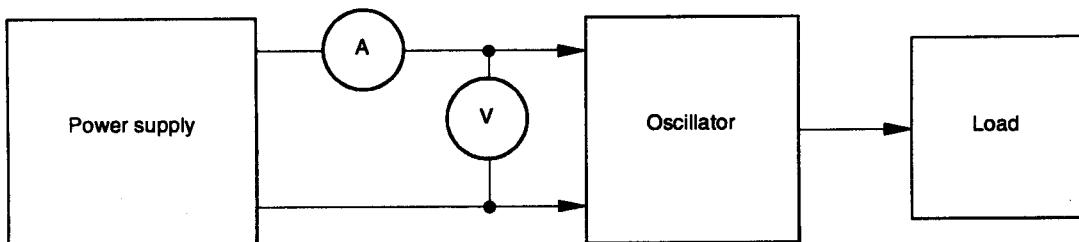


Figure 6 – Test circuit for oscillator input power measurement

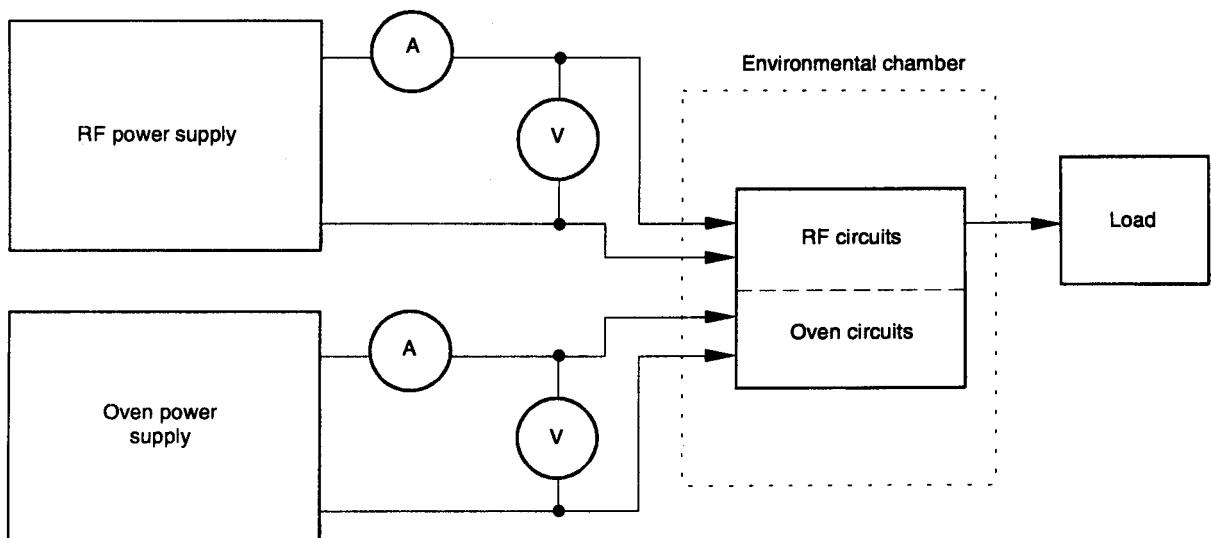
##### 4.5.3.2 Oven and oscillator input power

The oscillator shall be connected to the test circuit (see note to figure 7) and placed in the environmental chamber as shown in figure 7. The load and supply voltage(s) shall be as specified in the detail specification. Where the input power to the oscillator will be affected by forced air circulation, still air conditions shall be simulated by enclosing the oscillator in a draught shield, as described in 4.2.3. Readings of voltage and current shall be taken at the specified temperatures as stated in the detail specification (usually at the minimum and maximum of the operating temperature range, as well as at the reference temperature).

The temperature will normally be taken as the reference point temperature on the surface of the draught shield, when used. If peak power is specified, the transient values of voltage and current shall be measured when the environmental chamber is adjusted to each of the specified temperatures. In this case, it may be necessary to attach a recording meter to the ammeter and/or voltmeter, so as to measure adequately the transient values.

The oscillator and oven shall be allowed to reach thermal equilibrium at the operating temperature, while unenergized, prior to any measurement of peak power. Should peak power be required, the environmental chamber shall have a thermal time constant significantly less than that of the oven-oscillator combination being measured.

The input power is calculated using the measured values of voltage and current.



NOTE – The power to the oscillator may be supplied from the same power supply.

**Figure 7 – Test circuit for oven and oscillator input power measurement**

#### 4.5.3.3 Oven input power

To measure the oven input power only, the test procedure described in 4.5.3.2 shall be used, except that the power supply to the oscillator shall be disconnected.

#### 4.5.4 Output frequency

Output frequency measurements shall be made using either method 1 or method 2, according to the accuracy specified for the oscillator.

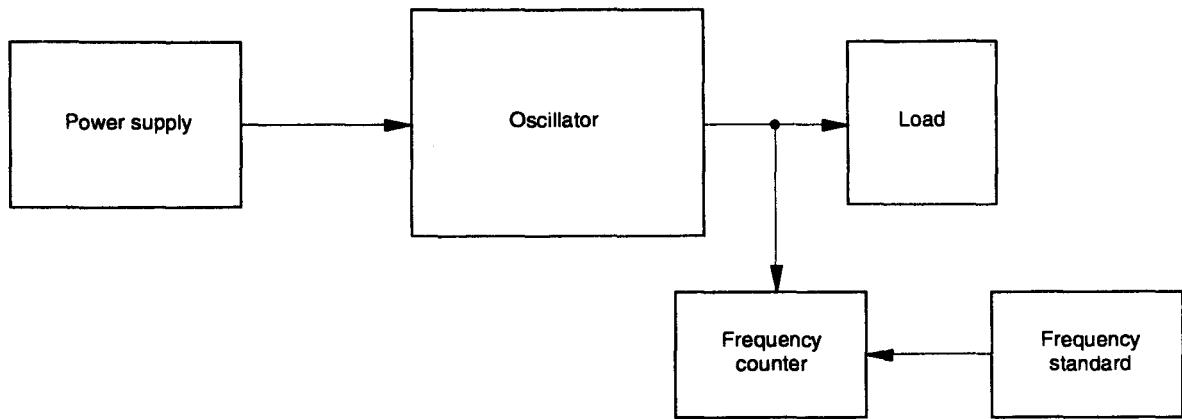
The following precautions shall be observed:

- the accuracy and resolution of the system shall always be an order better than that of the frequency to be determined;
- the oscillator shall be correctly loaded;
- the stability and accuracy of the system shall be verified by periodic checks of the frequency standard against an internationally recognized standard;
- for accurate measurements, it is essential that great care be taken to ensure that environmental conditions do not influence the results.

#### Method 1 – Measurement for accuracies less than or equal to $1 \times 10^{-8}$

The oscillator shall be connected, as shown in figure 8, to the specified supply voltage and load. It shall be allowed to stabilize for the specified time under normal operating conditions.

The frequency shall then be measured on the frequency counter. The frequency may be determined either by direct frequency measurement or by period averaging. The time period of measurement will normally lie in the range of 0,1 s to 10 s. Period averaging will generally be used for the measurement of frequencies less than 5 MHz.



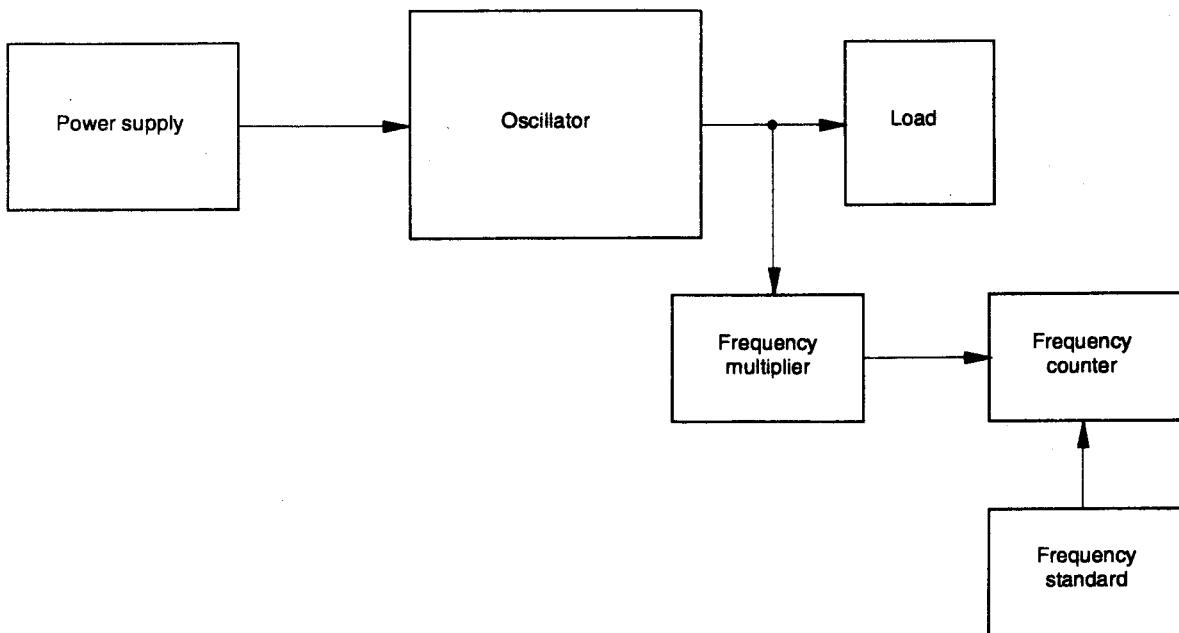
**Figure 8 – Test circuit for measurement of output frequency, method 1**

**Method 2 – Measurement for accuracies greater than  $1 \times 10^{-8}$**

The oscillator shall be connected, as shown in figure 9, to the specified supply voltage and load. It shall be allowed to stabilize for the specified time under normal operating conditions.

The frequency shall be measured on the frequency counter after multiplication to a frequency commensurate with the required accuracy. The time period will normally be in the range of 0,1 s to 10 s. For example a 2,5 MHz signal would need to be multiplied to 25 MHz to enable a measurement of frequency to be obtained to an accuracy better than  $1 \times 10^{-8}$  within 10 s.

Alternative methods include the use of a high speed counter in place of the frequency multiplier. It is also possible to use a system of phase comparison against a frequency synthesizer which is driven from a frequency standard, for accuracies of  $1 \times 10^{-10}$  or better.



**Figure 9 – Test circuit for measurement of output frequency, method 2**

#### **4.5.5 Frequency/temperature characteristics**

##### **4.5.5.1 Frequency at specified temperature(s)**

The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load using the test circuit shown in figure 10. The specified supply voltage shall then be applied to the oscillator.

Where the input power to the oscillator will be affected by forced air circulation, still air conditions shall be simulated by enclosing the oscillator in a draught shield as described in 4.2.3.

The chamber shall be allowed to stabilize at the specified temperature and, when the oscillator has reached equilibrium (see 4.2.2), measurements of the frequency shall be made using the appropriate measurement method given in 4.5.4.

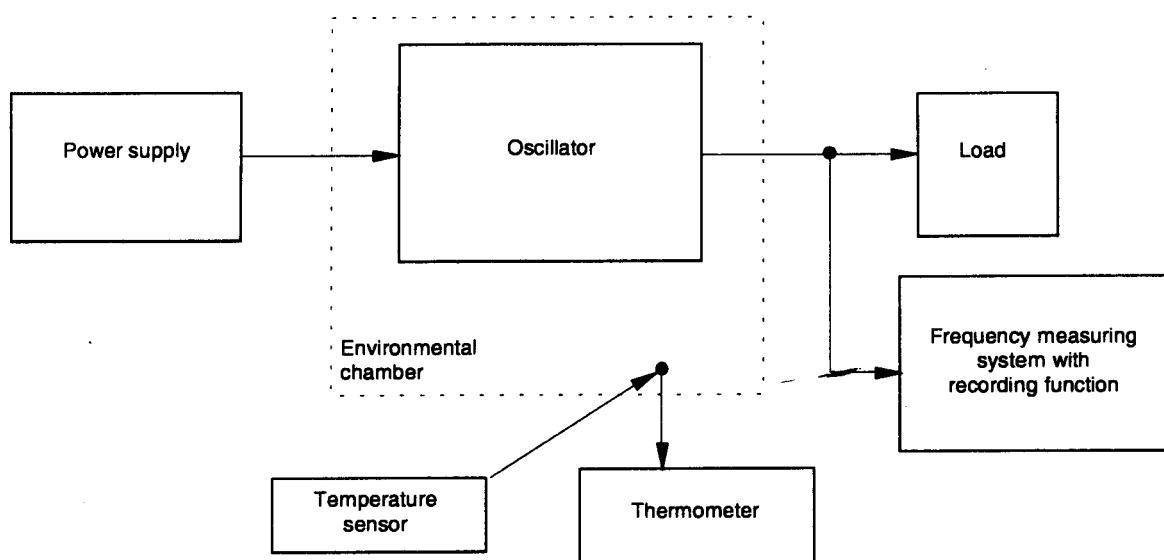


Figure 10 – Test circuit for measurement of frequency/temperature characteristics

#### 4.5.5.2 Total frequency excursion

The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load using the test circuit shown in figure 10. The specified supply voltage shall then be applied to the oscillator.

Where the input power to the oscillator will be affected by forced air circulation, still air conditions shall be simulated by enclosing the oscillator in a draught shield as described in 4.2.3.

The chamber shall be allowed to stabilize at a temperature extreme and, when the oscillator has reached equilibrium (see 4.2.2), the frequency and temperature shall be recorded using the appropriate frequency measurement method given in 4.5.4.

The test chamber temperature shall be changed in incremental steps of  $1,5\text{ }^{\circ}\text{C}$ , ensuring that equilibrium is reached after each temperature step, or changed at a rate of  $0,5\text{ }^{\circ}\text{C}/\text{min}$  to the other extreme of temperature, unless otherwise specified in the detail specification.

Recordings of the frequency and temperature shall be made during the test.

If it is required by the detail specification to determine the reproducibility of the frequency/temperature characteristics, the frequencies shall be recorded with temperature changes in both directions.

NOTE – In some applications, it may be required to determine the reproducibility of the frequency/temperature characteristics as the temperature is first increased from minimum to maximum, then decreased from maximum to minimum. Differences in the characteristics obtained during increasing and decreasing temperatures are called retrace errors, or hysteresis, and are of particular importance when testing TCXO devices.

#### 4.5.6 Frequency/load coefficient

Using a frequency measuring system as described in 4.5.4, measurements of the oscillator output frequency shall be made for the specified nominal load, minimum load and maximum load, all other operating parameters being maintained constant at their specified values. The load values shall then be calculated taking into account the effect of the measuring equipment connected to the output of the oscillator, which shall be included in the total load value.

#### 4.5.7 Frequency/voltage coefficient

Using a frequency measuring system as described in 4.5.4, and maintaining all other operating parameters at their specified values, measurement of the oscillator frequency shall be made when the power supply voltage is adjusted to its specified nominal value, to its minimum value and to its maximum value. In all cases, the specified stabilization time shall be allowed between adjustment of supply voltage and measurement of frequency.

A transient frequency excursion may occur immediately after adjustment of the power supply voltage, particularly if the device under test is either an OCXO or TCXO type. When the magnitude of this transient excursion is of importance, recording type meters shall be used to record the frequency excursion. The maximum permissible deviations during the transient interval shall be separately specified.

When required, an environmental chamber shall be used to maintain the ambient temperature at its specified value during the performance of this test.

#### 4.5.8 Frequency stability with thermal transient

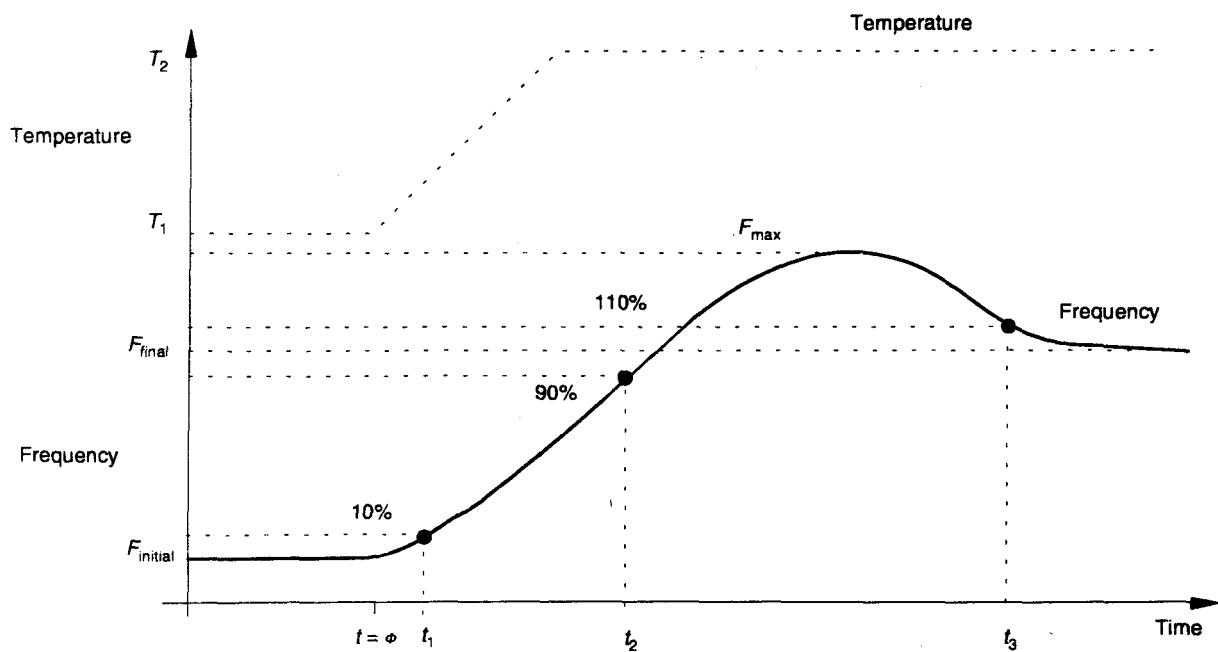
The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load, using the test circuit shown in figure 10. The specified voltage shall then be applied to the oscillator. The chamber shall be allowed to stabilize and the oscillator to reach equilibrium (see 4.2.2) at the specified initial temperature  $T_1$ . The oscillator output frequency shall be recorded.

The environmental chamber temperature shall then be changed at the specified rate to the final temperature  $T_2$ .

The oscillator output frequency and the environmental chamber temperature (as measured at the reference point) should be continuously recorded during and after this operation, resulting in a plot of both frequency change and temperature change similar to that in figure 11, from which the thermal response time and the overshoot may be determined.

**4.5.8.1** The overshoot of the transient excursion shall be specified in fractional parts of the nominal frequency (e.g. overshoot shall not exceed  $2 \times 10^{-7}$ ):

$$\text{overshoot} = \frac{F_{\text{max}} - F_{\text{final}}}{F_{\text{nominal}}}$$



$t = \phi$  = end of stabilization time

$t_1$  = time for frequency to change 10 % of the steady-state increment

$t_2$  = time for frequency to change 90 % of the steady-state increment

$t_3$  = time for frequency to reach 110 % of the steady-state increment on the recovery from overshoot (in the case where overshoot is greater than 10 %)

Figure 11 – Thermal transient behaviour of typical oscillator

**4.5.8.2** Unless otherwise specified, the thermal response time is the time interval between the instant the frequency has changed 10 % of the overall change and the instant the frequency has attained a value within 10 % (of the change) of its final frequency.

There are two possible cases, as shown by the sample recordings in figure 11:

- when the overshoot is less than 10 %, the thermal response time is equal to  $t_2 - t_1$  min;
- when the overshoot is equal or greater than 10 %, the thermal response time is equal to  $t_3 - t_1$  min.

#### 4.5.9 Oscillation start-up

The purpose is to determine the reliable start-up of the oscillation amplitude and to measure the start-up time.

Figure 12 depicts the generalized oscillator circuit.

The start-up characteristics of a real crystal oscillator depend on the following major factors.

Oscillator stage:

- noise factor of the active device;
- open loop gain (or excess negative resistance) of the oscillation sustaining stage;
- amplitude limiting of the active circuit;
- loaded Q (or effective bandwidth of the resonator);
- drive level dependency of the crystal resonance resistance.

Output stage:

- analogue sinusoidal output;
- logic output.

Internal power lines:

- blocking capacitors;
- voltage regulators.

Supply voltage:

- rise time, soak time, off time;
- output impedance.

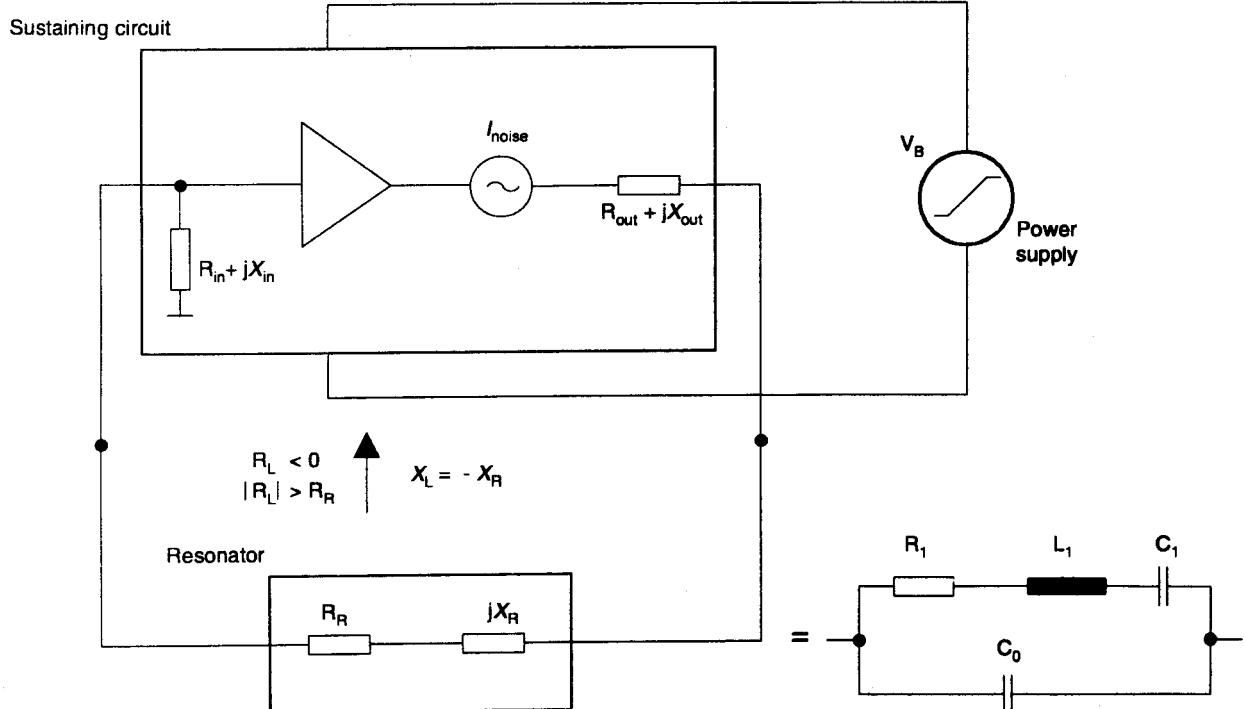


Figure 12 – Generalized oscillator circuit

4.5.9.1 Start-up behaviour

In order to determine whether the oscillation starts up reliably, the oscillator shall be connected to the test circuit for start-up behaviour shown in figure 13.

The oscillator shall be connected to a programmable power supply. The r.f. output signal and the supply voltage are registered by an oscilloscope, the time scale of which is suitably set to display the whole start-up interval.

The supply voltage ramps linearly from zero to the nominal operating voltage. The ramp time  $t_{ramp}$  is chosen to be at least 100 to 1 000 times the specified or expected start-up time of the oscillator.

The oscillator shall show a regular and repeatable start-up behaviour within the time interval of the supply voltage ramp, as shown in figure 14.

#### Specified conditions

The following test conditions shall be stated in the detail specification:

- power supply voltage;
- load details;
- start-up time;
- in case of VCXO, d.c. control voltage.

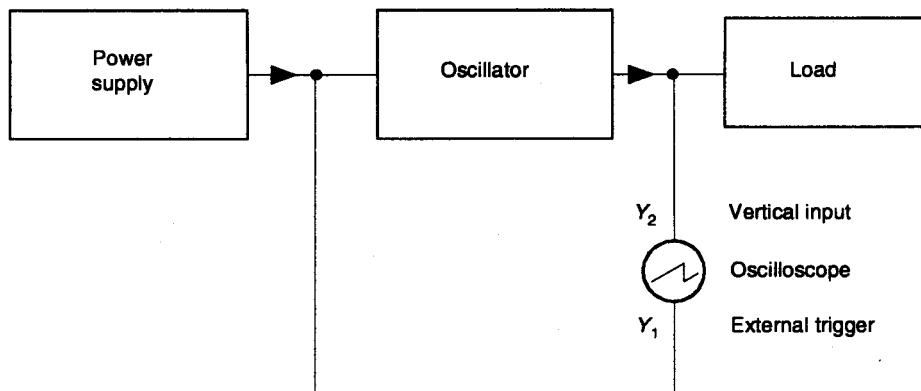
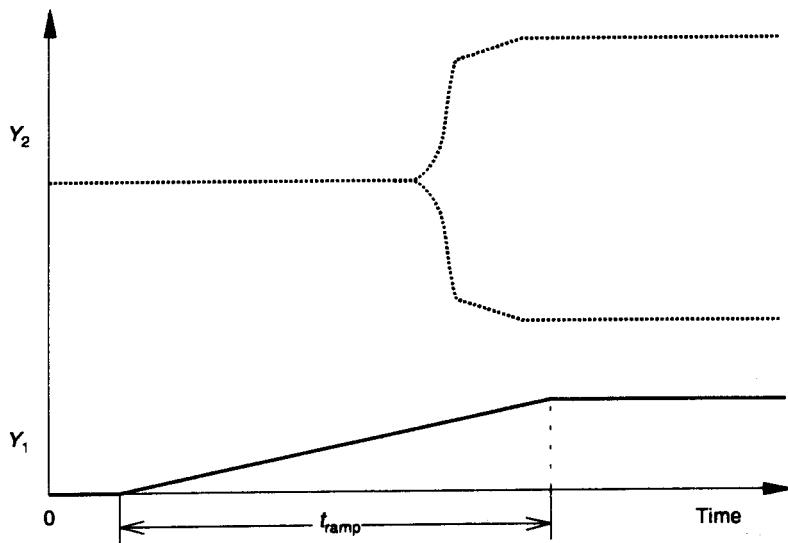


Figure 13 – Test circuit for start-up behaviour and start-up time measurement



**Figure 14 – Typical start-up behaviour with slow supply voltage ramp**

#### 4.5.9.2 Start-up time

In order to measure the start-up time of oscillation  $t_{SU}$  under specified conditions, the oscillator shall be connected to a programmable power supply (see figure 13).

The r.f. output signal and the supply voltage shall be registered by an oscilloscope, the time scale of which is suitably set to display the whole start-up interval.

The supply voltage ramps up linearly from zero to the nominal operating voltage. The ramp time  $t_{ramp}$  is chosen to be less than one tenth of the specified or expected start-up time of the oscillator.

The start-up time  $t_{SU}$  is measured as the difference between the starting point of the d.c. ramp and the time when the r.f. output signal fulfils certain conditions which are given below:

a) quasi-sinusoidal waveforms

the signal envelope is 90 % of the steady-state peak-to-peak amplitude, unless otherwise specified;

b) pulse waveforms

the output pulse sequence is periodical near the steady-state frequency while its low level  $V_{OL}$  remains below  $V_{OL}$  and its high level  $V_{HI}$  exceeds  $V_{OH}$  permanently, where  $V_{OH}$  and  $V_{OL}$  are defined by the applicable logic family.

#### Precaution

Logic output may show spurious oscillations prior to the appearance of the steady-state signal.

NOTE – Make sure that the internal blocking capacitors of the oscillator are discharged before the start of the measurement.

An example is given in figure 15.

The described procedure can be applied either as a single shot or as a periodical measurement. In the latter case, the following conditions shall be fulfilled (see figure 16):

$t_{\text{ramp}}$  as above;

$t_{\text{hold}} \geq 100 t_{\text{SU}}$ ;

$t_{\text{off}}$ : minimum length shall be chosen such that a further prolongation does not change the result for  $t_{\text{SU}}$ , for example  $t_{\text{off}} \geq 100 t_{\text{SU}}$ .

During  $t_{\text{off}}$  the supply voltage terminal of the oscillator shall be short-circuited to ground in order to discharge internal blocking capacitors properly.

NOTE – The factor 100 in formulae for  $t_{\text{hold}}$  and  $t_{\text{off}}$  can be reduced to smaller volumes, however, it should be verified that the measured start-up time is not changed, particularly for high Q resonators.

### Precaution

The power supply shall be able to deliver sufficient current to realize the specified voltage ramp at the oscillator supply voltage terminal. It shall be able to drain the discharge current of the oscillator during the  $t_{\text{off}}$  period.

### Specified conditions

The following test conditions shall be stated in the detail specification:

- power supply voltage;
- load details;
- start-up time;
- in the case of VCXO: d.c.control voltage.

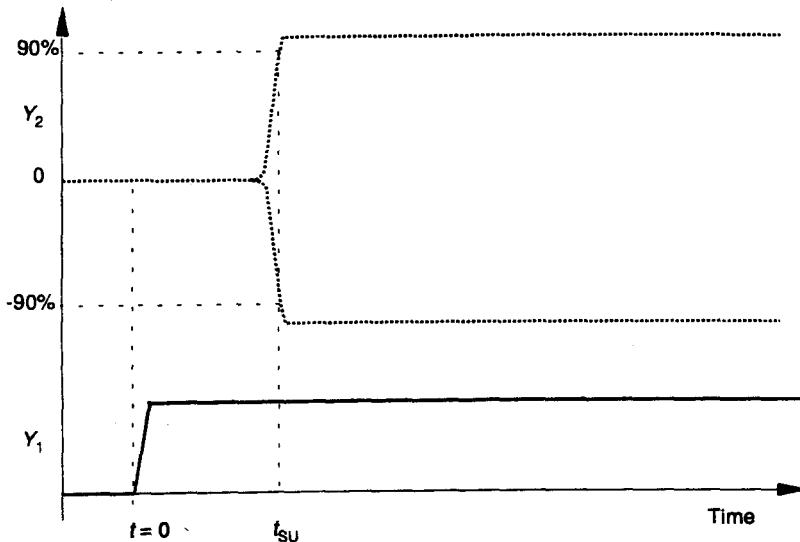


Figure 15 – Definition of start-up time

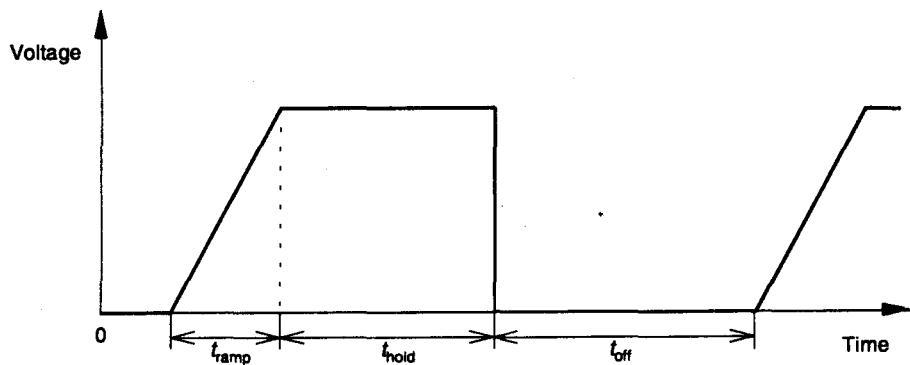


Figure 16 – Supply voltage waveform for periodical  $t_{SU}$  measurement

#### 4.5.10 Stabilization time

The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load using the test circuit shown in figure 10. The frequency measurement used shall be as described in 4.5.4. The temperature of the chamber shall be adjusted to that specified in the detail specification. The oscillator shall then be energized and the output frequency registered on the recording meter as a function of time. The stabilization time  $t_s$  shall be the time taken for the oscillator output frequency to remain within a specified tolerance of its long-term value determined after a specified elapsed time (see figure 17).

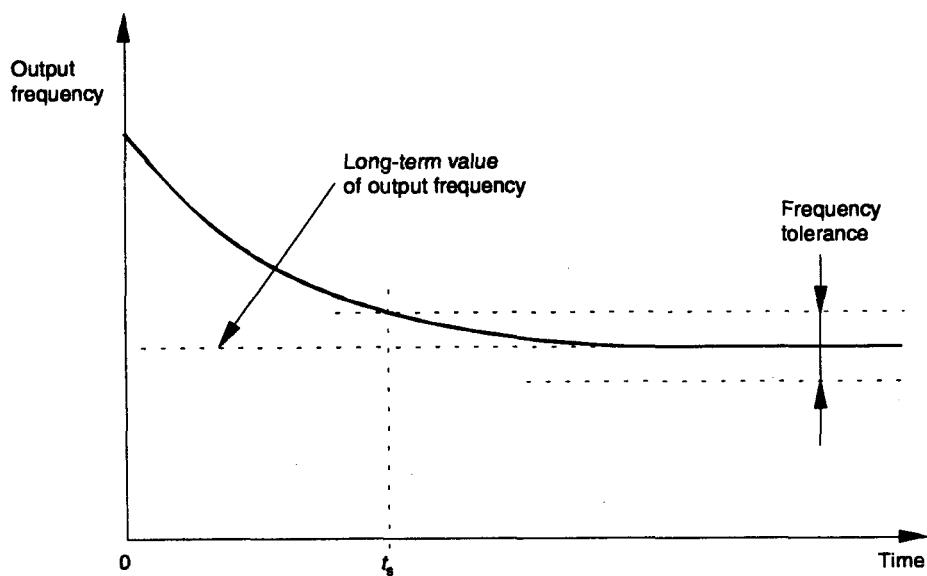


Figure 17 – Typical oscillator stabilization characteristic

#### 4.5.11 Frequency adjustment range

The oscillator shall be connected as shown in 4.5.4 and, where necessary, to an appropriate control voltage. The oscillator shall be energized and allowed to stabilize for the specified time under normal operating conditions. The means by which the oscillator output frequency adjustment is made shall be adjusted to its maximum and minimum and the output frequency measured, unless otherwise stated in the detail specification.

#### 4.5.12 Retrace characteristics

The unenergized oscillator shall be placed in the environmental chamber and connected to the specified load, using the test circuit shown in figure 10. The chamber shall be maintained at a temperature in the range 20 °C to 30 °C, controlled within  $\pm 0,5$  °C, unless otherwise stated in the detail specification. The oscillator shall be energized and all operating parameters adjusted to specified values, after which the frequency shall be measured as a function of time.

Following a specific period of operation ( $t_1$ , figure 18, which shall exceed the stabilization time), the output frequency shall be recorded. The oscillator is then turned off, and allowed to assume the specified storage temperature for the specified time period  $t_2$ . At the end of the storage period, power is again applied, and frequency recorded as a function of time. The retrace time  $t_r$  is the time period following application of power required for the output frequency to return to within the specified tolerance of the value recorded before turn-off.

If the oscillator is stored (during period  $t_2$ ) elsewhere than in the environmental chamber, adequate time shall be allowed for the oscillator to settle to the temperature specified for frequency measurement before any measurement of frequency takes place; this stabilization time (in an unenergized condition) should be taken as a part of the storage period  $t_2$ .

NOTE – Provision is made for a separate specification of measurement temperature as, although the temperatures may be the same, the tolerance of the storage temperature may be considerably greater than that of the measurement temperature.

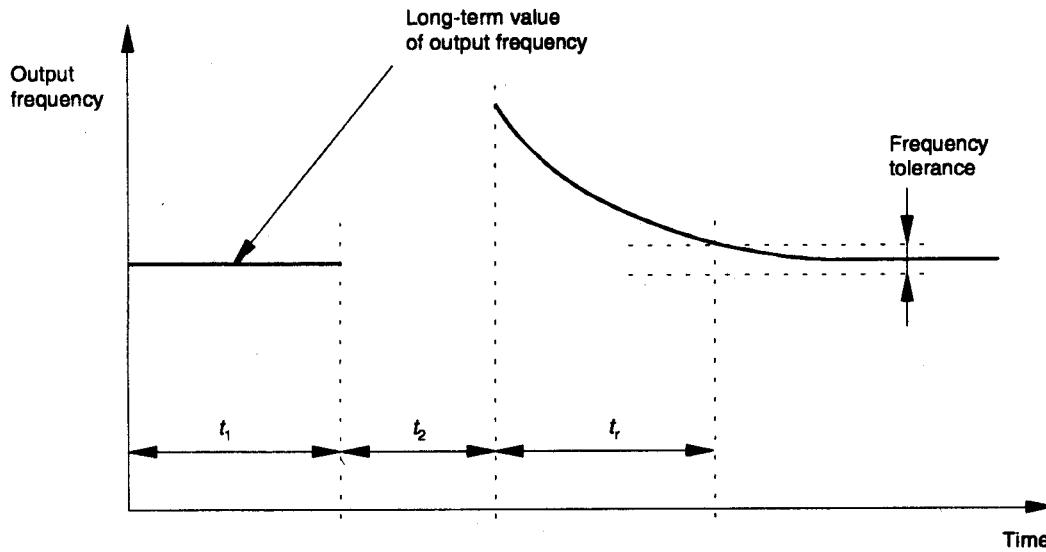


Figure 18 – Example of retrace characteristic

#### 4.5.13 Oscillator output voltage (sinusoidal)

The oscillator shall be connected, as shown in figure 19, to the specified supply voltage and load. It shall be allowed to stabilize for the specified period of time. The output voltage shall be measured across the load, and shall remain within the specified limits over the range of any frequency adjustment specified. Measurements shall be performed at the reference temperature, but may be carried out over the operating temperature range if required by the detail specification. Measurement shall be made with an r.f. voltmeter for r.m.s. voltages and an oscilloscope for peak-to-peak voltages.

In the case of quasi-sinusoidal waveforms, the measurement of output power shall always be performed by a direct-reading power meter or by means of a true r.m.s. reading voltmeter.

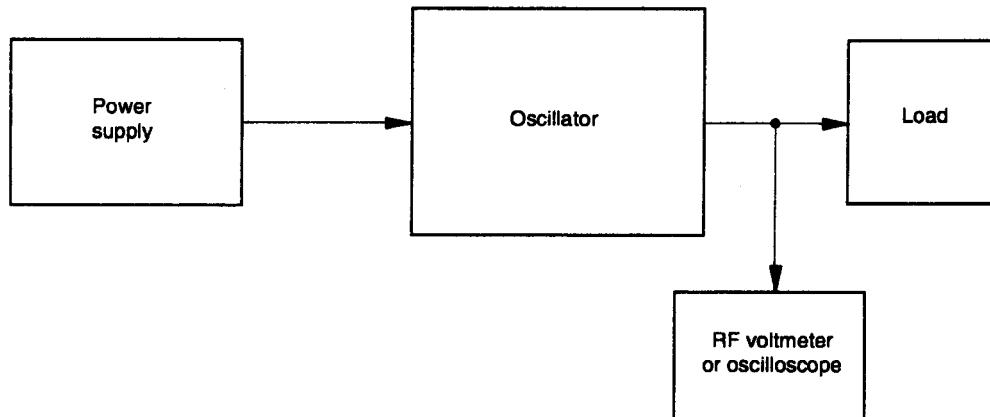


Figure 19 – Test circuit for the measurement of output voltage

#### 4.5.14 Oscillator output voltage (pulse waveform)

The oscillator shall be connected, as shown in figure 20, with the specified load (see annex A for details of load circuits for logic drive).

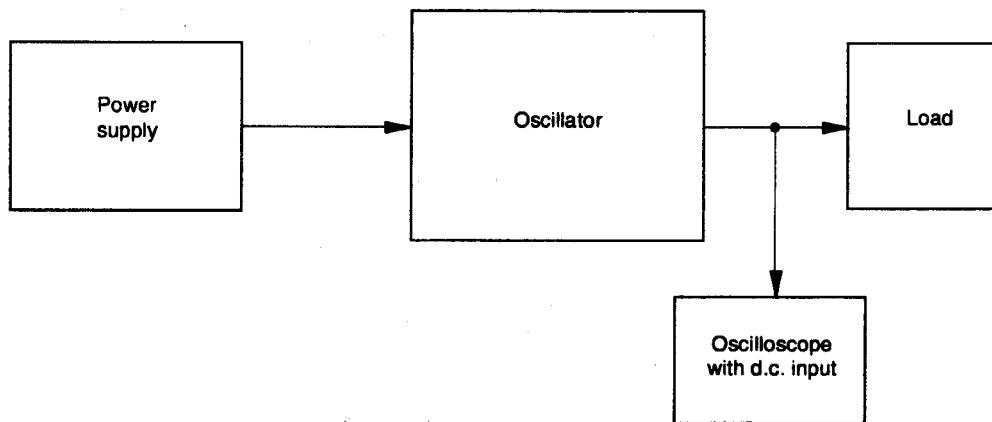


Figure 20 – Test circuit for the measurement of pulse outputs

The high and low level output voltages (see figure 3) shall be measured on the oscilloscope, and shall be within the limits specified in the detail specification.

#### 4.5.15 Oscillator output waveform (sinusoidal)

The oscillator shall be connected to the specified load, as shown in figure 21.

The spectrum analyzer shall be adjusted to display a frequency range which embraces the appropriate harmonics of the oscillator. Typical quasi-sinusoidal waveforms are shown in figure 22, and typical frequency spectra are shown in figure 23.

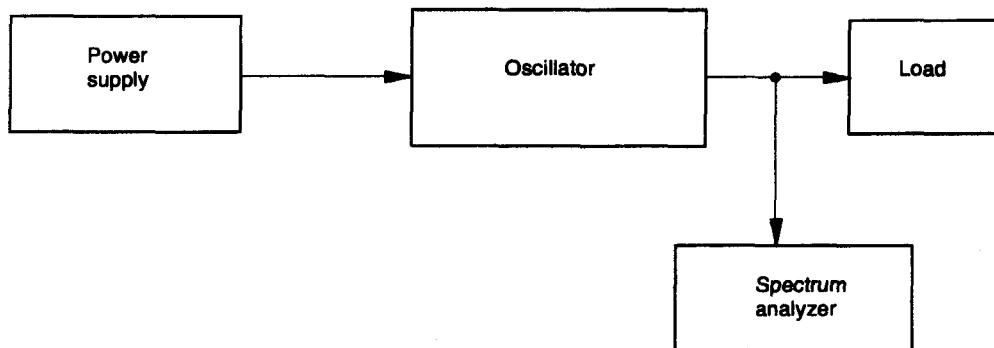


Figure 21 – Test circuit for harmonic distortion measurement

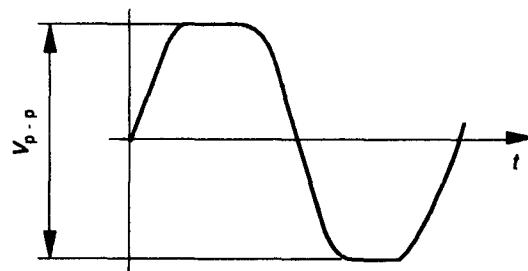


Figure 22a – Symmetrical

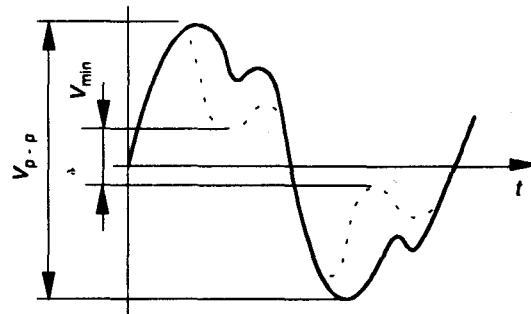


Figure 22b – Large odd harmonic content

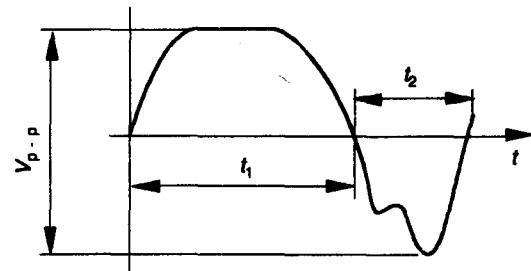


Figure 22c – Large even harmonic content

Figure 22 – Quasi-sinusoidal output waveforms

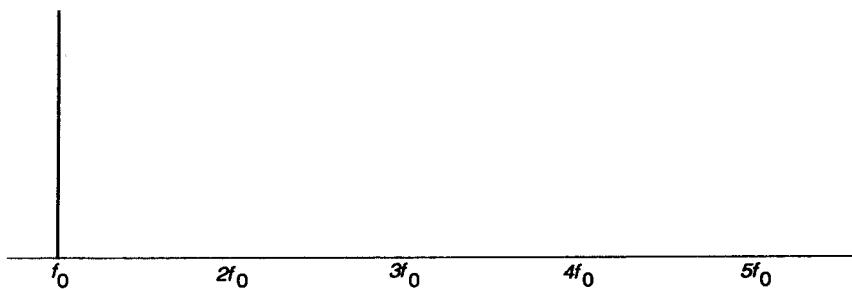


Figure 23a – Ideal spectrum

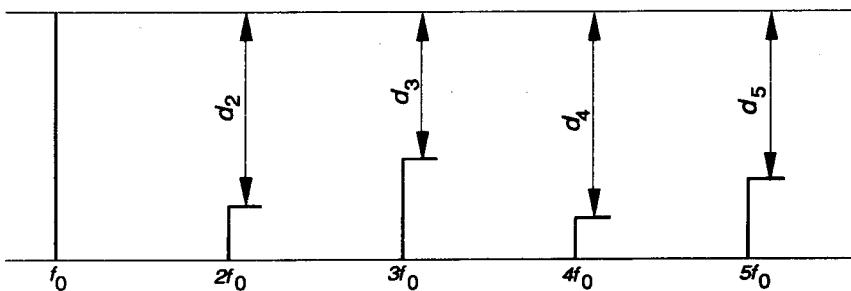


Figure 23b – Spectrum showing severe harmonic distortion

Figure 23 – Frequency spectrum for harmonic distortion

The spectra on the spectrum analyzer shall be measured, usually directly in decibels, as a power ratio with respect to the carrier power, expressed in decibels or, alternatively, the percentage distortion of the harmonic shall be calculated as follows:

$$D_x = \frac{100}{10^{\frac{d_x}{20}}}$$

where

$D_x$  is the percentage of harmonic distortion;

$d_x$  is the difference in level of fundamental and harmonic (in decibels) as measured on the spectrum analyzer;

$x$  is the harmonic number.

When using this test method it shall be necessary to observe the following precautions:

- care shall be taken to ensure that the distortion is not produced in the input mixer of the spectrum analyzer;
- non-linear distortion (having the appearance of harmonic distortion) will be produced if the input mixer is over-loaded. This may be checked by placing an attenuator between the oscillator and the spectrum analyzer, and taking measurements at various power levels. The attenuator setting should not affect the percentage of harmonic distortion.

NOTE – The total harmonic distortion may be obtained from a summation of the individual harmonically related responses.

$$D_{\text{total}} = 100 \left[ 10^{\frac{-d_2}{10}} + 10^{\frac{-d_3}{10}} + \dots + 10^{\frac{-d_n}{10}} \right]^{-1/2}$$

#### 4.5.16 Oscillator output waveform (pulse)

The oscillator shall be connected, as shown in figure 20, and with the specified load (see annex A for details of load circuits for logic drive).

##### 4.5.16.1 Rise and decay times (see 2.2.33 and 2.2.34)

Measurements shall be made on both the rising and falling edges between the limits of the input voltage over which the operation of the particular logic family is guaranteed, for example, for TTL and CMOS logic families between  $V_{OH\ min.}$  and  $V_{OL\ max.}$  or at the 10 % and 90 % points with respect to the flat portion of the maximum amplitude level. Overshoot shall be disregarded in this measurement if its peak does not exceed the limits specified for the steady-state levels, or if the cause for the overshoot can be traced to inductances external to the oscillator and oscilloscope.

Where higher accuracies are required the following correction formula shall be used:

$$t_a = \sqrt{(t_i)^2 - (t_s)^2}$$

where

$t_i$  is the measured rise or decay time;

$t_s$  is the oscilloscope rise or decay time;

$t_a$  is the actual time.

##### 4.5.16.2 Pulse duration (see 2.2.32)

The pulse duration of the oscillator shall be measured with the oscilloscope when the rise and decay times are measured. Unless otherwise specified, measurements shall be made at the midpoint between  $V_{OL\ max.}$  and  $V_{OH\ min.}$  or at the 50 % level.

##### 4.5.16.3 Symmetry (see 2.2.36)

When specified the symmetry of the waveform from the oscillator shall be determined when the rise and decay times are measured. Unless otherwise specified, measurements shall be made at the midpoint between  $V_{OL\ max.}$  and  $V_{OH\ min.}$  or at the 50 % level.

#### 4.5.17 Oscillator output power (sinusoidal)

The test procedure shall be carried out as for 4.5.13, output voltage. The output power shall be calculated from the r.m.s. output voltage and the load impedance or, alternatively, it may be read directly from an appropriate power meter. In the case of quasi-sinusoidal waveforms, the measurement of output power shall always be performed by a direct-reading power meter or by means of a true r.m.s. reading voltmeter.

#### 4.5.18 Oscillator output impedance (sinusoidal)

The oscillator shall be connected, as shown in figure 20, except that the load shall be a precision ( $\pm 1\%$  non-reactive) resistor  $R_L$ , equal to the specified load minus 10 %. The oscillator shall be energized and allowed to stabilize for the specified period of time after which the output voltage  $V_L$  shall be measured. The load shall then be replaced with a precision ( $\pm 1\%$  non-reactive) resistor  $R_H$ , equal to the specified load plus 10 % and the output voltage  $V_H$  measured. The output impedance shall be calculated using the expression:

$$Z = \frac{R_L R_H (V_H - V_L)}{V_L R_H - V_H R_L}$$

NOTE – This method is only valid if the output impedance of the oscillator is resistive, and it is not accurate when the output resistance is considerably lower than the load impedance.

#### 4.5.19 Re-entrant isolation

The oscillator shall be connected to the test circuit, as shown in figure 24. The ports between which the isolation is to be measured shall be shorted together. The level and frequency of the re-entrant signal, as specified, shall be set on the signal generator. Using the spectrum analyzer (or selective voltmeter), the output level of this signal shall be measured at the port to which the signal is not being applied (or at the specified port in the case of oscillators with multiple ports). The shorting link shall then be removed and the output level again measured.

The ratio of the two signals measured with and without the shorting link (usually expressed in decibels) is the re-entrant isolation between the appropriate ports at that frequency. This ratio shall be as stated in the detail specification.

When carrying out this test, the following precautions shall be observed:

- the loads presented to the oscillator are a combination of the output impedance of the signal generator, the input impedance of the spectrum analyzer (or selective voltmeter) and any externally applied loads;
- care shall be taken to prevent overloading of the spectrum analyzer (or selective voltmeter), as this will cause signal limiting and an apparent reduction in re-entrant isolation;
- if isolation is to be measured at a frequency which is a harmonic of the oscillator, then a pessimistic value of re-entrant isolation will be obtained. However, if the harmonic level is considerably lower than the isolation to be measured, a usable result can still be achieved. Where the harmonic content of the output signal is high, it is necessary to disable the oscillator (that is, to cause the device to cease oscillation while still remaining energized) before measurements can be made.

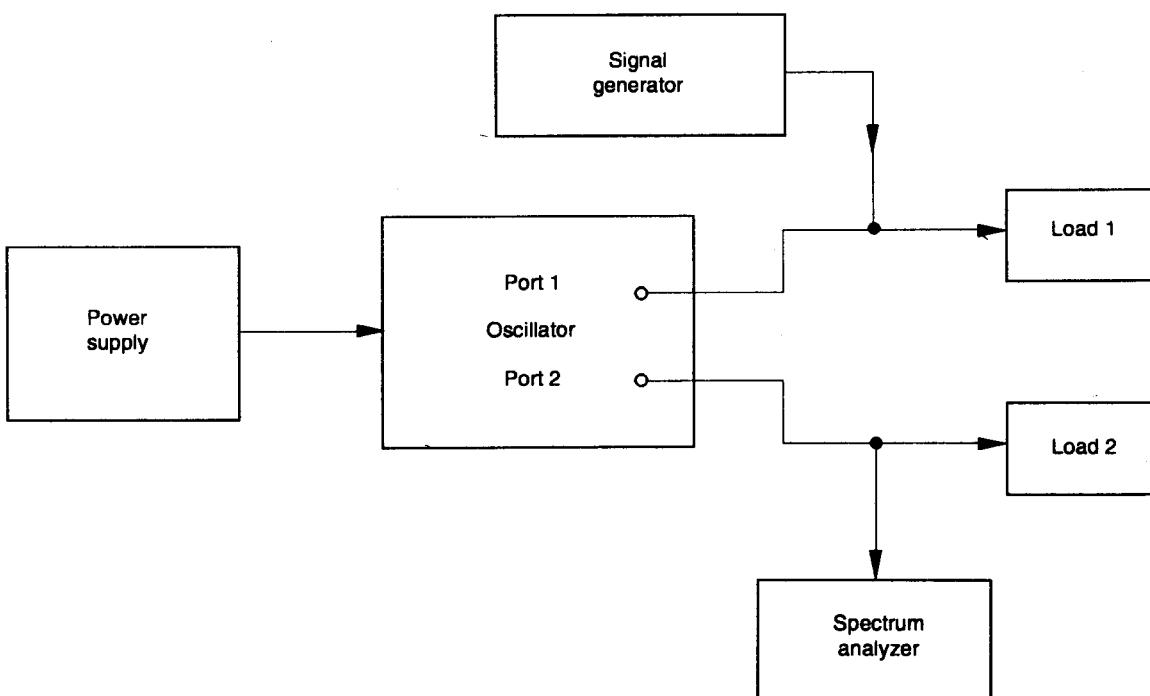


Figure 24 – Test circuit for the determination of isolation between output ports

#### 4.5.20 Output suppression of gated oscillators

The oscillator shall be connected to the test circuit, as shown in figure 25, and the tests carried out as follows.

The specified signal necessary to gate the ON output of the oscillator shall be applied, and the level of the output at its fundamental frequency and at any harmonic frequency or frequencies, as specified, shall be measured on the spectrum analyzer. The specified signal necessary to gate the OFF output of the oscillator shall then be applied and the new output level(s) measured.

The ratio of the ON and OFF output levels, usually expressed in decibels, is the output suppression at a particular frequency, and shall be as specified in the detail specification.

Care shall be taken to prevent overloading of the spectrum analyzer, as this will cause signal limiting and an apparent reduction in output suppression.

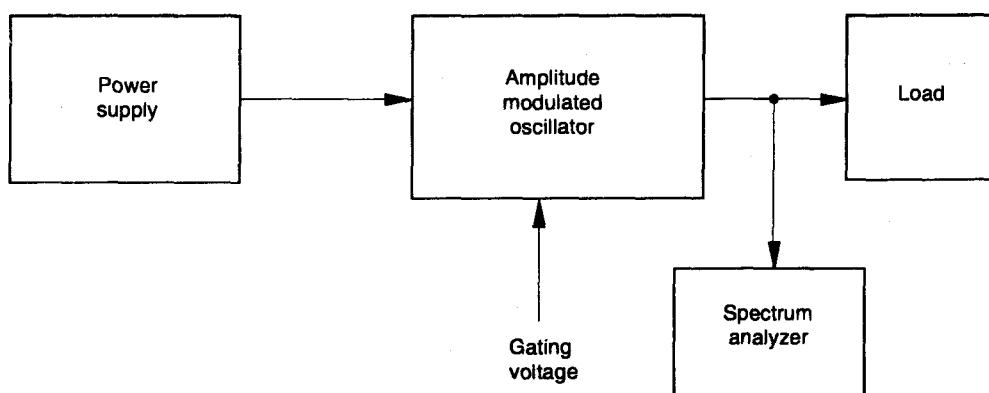


Figure 25 – Test circuit for measuring suppression of gated oscillators

#### 4.5.21 Tri-state output characteristics

##### 4.5.21.1 Tri-state disable mode output current

This test is used to determine the short-circuit output current drawn from an oscillator with a tri-state output when held in the disable mode.

The oscillator shall be connected as shown in figure 26. With the enable/disable pin connected to the appropriate d.c. level via switch 1, that is to the specified supply voltage for oscillators designed for enable low, or to earth for those designed for enable high, the power to the oscillator shall be applied.

The enable/disable voltage levels shall be as specified in the detail specification. However, care shall be taken to ensure that the voltages applied to the enable/disable pin and the output pin cannot exceed the voltage applied to the oscillator.

The oscillator output is then switched, by switch 2, in turn between the supply voltage and earth, and the output current at each setting measured.

The maximum permissible output current in the disable mode, as specified in the detail specification, shall not be exceeded.

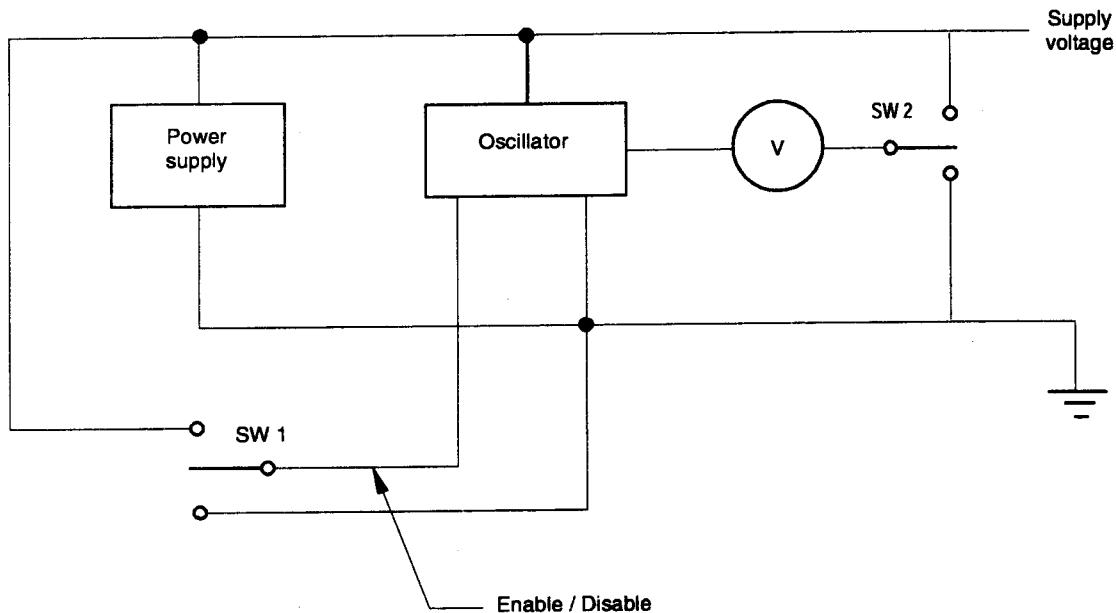


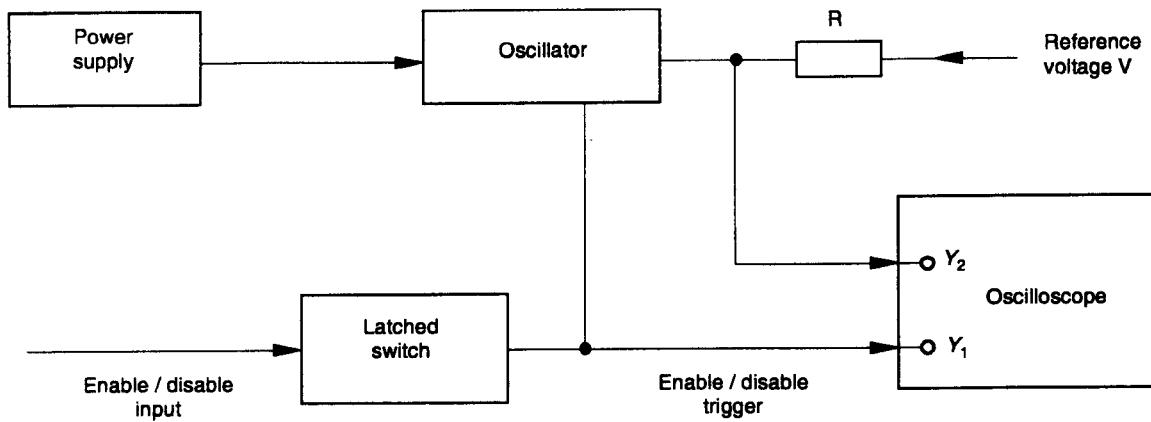
Figure 26 – Test circuit for tri-state disable mode output current

#### 4.5.21.2 Output gating time

To measure the time taken for the oscillator output stage to switch between the enable and disable modes, the oscillator shall be connected as shown in figure 27. The value of  $R$  shall be chosen so that the time constant formed by  $R$  and the oscilloscope input capacitance shall not affect the measurement accuracy.

The specified supply, reference, enable/disable voltages shall be applied to the oscillator, care being taken to ensure that the enable/disable voltages do not exceed the value of the supply voltage.

With an oscilloscope adjusted to trigger from either the enabling or disabling transition of the enable/disable input signal, as appropriate, and displaying the corresponding oscillator transition, together with the trigger transition, the gating time between the trigger transition and the time when the oscillator output stabilizes to the reference voltage shall be measured.



where

$$V = \frac{(V_{OH} - V_{OL})}{2} + V_{OL} \text{ is the reference voltage;}$$

$V_{OL}$  is the oscillator low level output voltage;

$V_{OH}$  is the oscillator high level output voltage.

Figure 27 – Test circuit for output gating time – tri-state

#### 4.5.22 Amplitude modulation characteristics

##### 4.5.22.1 Amplitude modulation index

###### Test A

This test procedure shall be used for a modulation index greater than 0,1 and less than 1,0. The oscillator shall be connected to the specified load, as shown in figure 28, and the specified modulating signal applied. Measurements of  $x$  and  $y$  (see figure 29) on the waveform shall be taken, and the modulation index ( $m$ ) calculated from the expression:

$$m = \frac{y - x}{y + x}$$

The index obtained shall be as stated in the detail specification and the percentage modulation shall be  $100 m \%$ . This method of measurement shall not be used when  $m$  is less than 0,1 because of inherently low measurement accuracy.

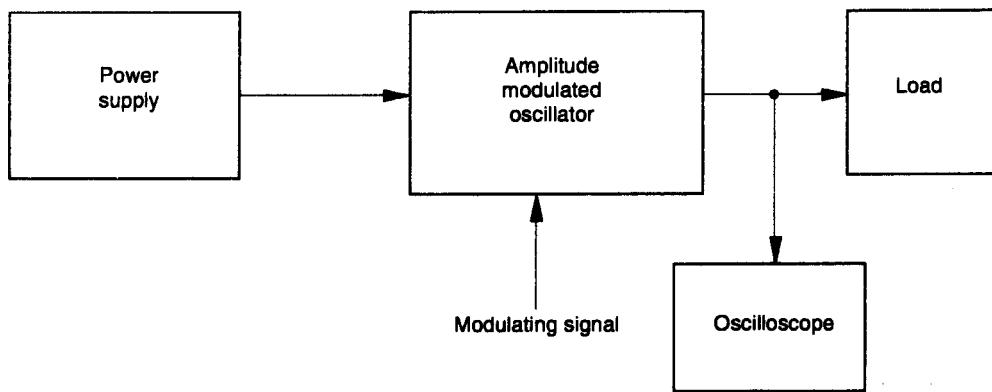


Figure 28 – Test circuit for modulation index measurement

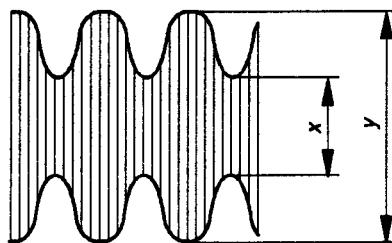


Figure 29 – Modulation waveform for index calculation

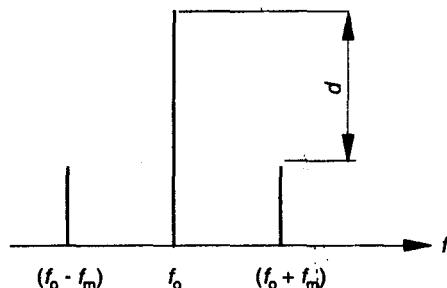
NOTE 1 – The accuracy for this method is unaffected by the presence of frequency modulation.

NOTE 2 – This method is valid for non-sinusoidal waveforms.

#### Test B

The test procedure shall be used for a modulation index less than 0,1.

The oscillator shall be connected to the specified load, as shown in figure 28, except that the oscilloscope shall be replaced by a spectrum analyzer having an i.f. bandwidth sufficiently narrow to provide adequate discrimination between the oscillator output and its sideband signals. With the specified modulating signal applied to the oscillator, the spectrum analyzer shall be adjusted to present a display of the frequency spectrum in the region of the output frequency of the oscillator, using a logarithmic signal amplitude scale (see figure 30).



$f_0$  = oscillator output frequency  
 $f_m$  = frequency of modulating signal  
 $f_0 - f_m$  = lower sideband signal frequency  
 $f_0 + f_m$  = upper sideband signal frequency  
 $d$  = difference between the oscillator output signal frequency ( $f_0$ ) level and the level of either of the sideband signals, in decibels

Figure 30 – Logarithmic signal amplitude scale

The modulation index ( $m$ ) shall be calculated using the expression:

$$m = 10^{\frac{6-d}{20}} \quad (m < 0,1)$$

where

$d$  is the difference between the oscillator output signal frequency ( $f_0$ ) level and the level of either of the sideband signals, in decibels.

The modulation index shall be as stated in the detail specification.

Care shall be taken to prevent overloading of the spectrum analyzer, causing signal limiting. This may be checked by placing an attenuator between the oscillator and the spectrum analyzer, and taking measurements at various power levels; the attenuator setting should not affect the value of  $d$  obtained.

NOTE 1 – This method cannot readily be used if significant resultant frequency modulation is present (see 4.5.22.7), usually causing the two sideband signals to be unequal in amplitude. The effect of the resultant f.m. on the spectrum analyzer display may be reduced by choosing a high modulating signal frequency (frequency modulation index  $\beta \propto \frac{1}{f_m}$ ).

NOTE 2 – This method cannot readily be used if the modulation waveform is non-sinusoidal, whether because of harmonic content in the modulating signal or because of a.m. non-linear distortion (see 4.5.22.3).

#### 4.5.22.2 Amplitude modulation sensitivity

The oscillator shall be connected to the specified load as shown in figure 31. The signal generator providing a modulating signal at the specified frequency shall be connected to the external modulation terminal of the oscillator. Its output shall be set to the specified amplitude as measured by the oscilloscope or r.f. voltmeter. The modulation index of the output signal shall be measured as described in 4.5.22.1 (as appropriate).

In general, the amplitude modulation sensitivity is taken as the percentage modulation peak-to-peak voltage of the modulating signal and shall be as stated in the detail specification.

NOTE – This method may be used to determine the immunity of an oscillator to power supply line ripple etc., by superimposing the modulating signal on the d.c. supply voltage.

#### 4.5.22.3 Amplitude modulation distortion (non-linearity)

The oscillator shall be connected to the specified load as shown in figure 31, except that the oscilloscope shall be replaced by a spectrum analyzer having an i.f. bandwidth sufficiently narrow to provide adequate discrimination between the oscillator output and its sideband signals.

A sinusoidal modulating signal at the specified frequency, and at a level such as to modulate the oscillator to the specified modulation index, shall be applied to the external modulation terminal of the oscillator; the spectrum analyzer shall be adjusted to present a display of the frequency spectrum in the region of the output frequency of the oscillator (see figure 32).

The second, third, etc. harmonic distortion is usually expressed as  $d_2$ ,  $d_3$ , etc. decibels, but may also be expressed as  $\frac{100}{10^{20}} \frac{d}{d}$  percentage distortion for each individual harmonic.

The distortion shall be within the limits stated in the detail specification.

When carrying out this test, the following precautions shall be observed:

- care shall be taken to prevent overloading of the spectrum analyzer, causing an apparent increase in modulation distortion. This may be checked by connecting an attenuator between the oscillator and the spectrum analyzer, and taking measurements at various power levels.

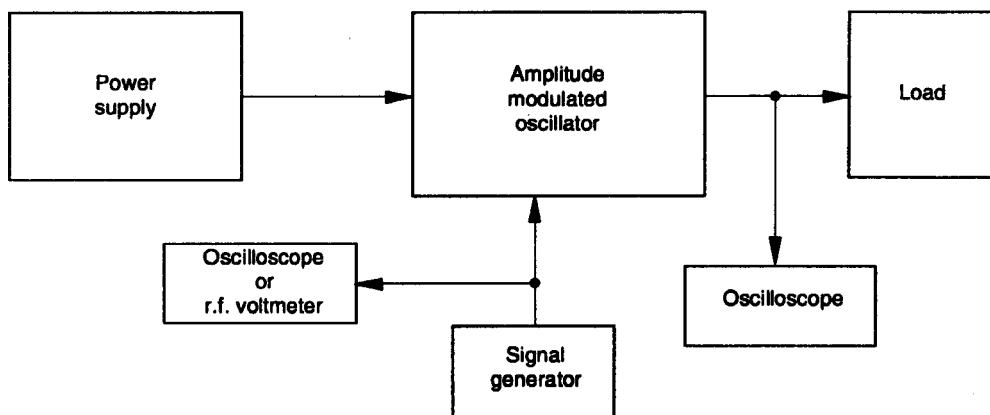
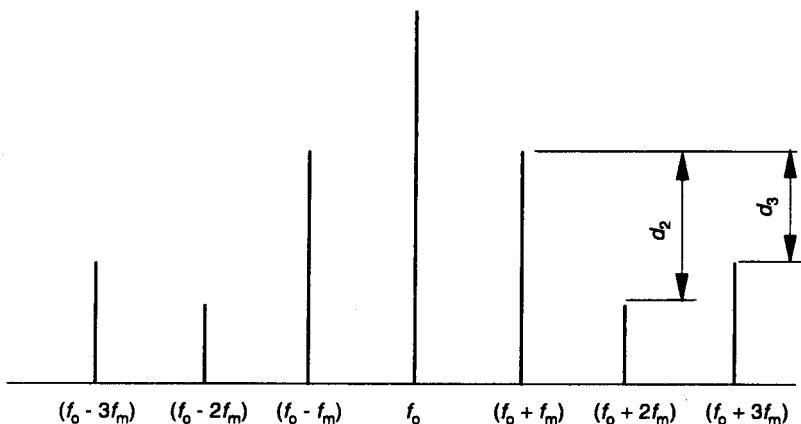


Figure 31 – Test circuit to determine amplitude modulation sensitivity



where

$f_o$  = oscillator output frequency

$f_m$  = frequency of modulating signal

$(f_o - f_m)$  = lower sideband caused by the modulating signal

$(f_o - 2f_m)$  = lower sideband caused by the second harmonic of the modulation signal

$(f_o - 3f_m)$  = lower sideband caused by the third harmonic of the modulation signal

**Figure 32 – Frequency spectrum of amplitude modulation distortion**

The attenuator setting should not affect the measurement of modulation distortion, that is the values of  $d_2$ ,  $d_3$ , etc. If the harmonic content of the modulating signal is significant, the results obtained shall be corrected, or the modulating signal filtered so as to reduce its harmonic content.

NOTE – Total modulation distortion may be assessed by detecting the output of the oscillator and measuring this signal with an appropriate distortion analyzer; this method measures the total sideband content of an amplitude modulated signal. The result may be obtained from the measurements made with a spectrum analyzer by summation of the sideband signals:

$$\text{Total distortion} = \frac{100}{\sqrt{\frac{-d_2}{10} + \frac{-d_3}{10} + \dots}}$$

#### 4.5.22.4 Amplitude modulation frequency response

The test procedure given in 4.5.22.2 with a sinusoidal modulating signal applied shall be used. The amplitude modulation sensitivity at a specified reference frequency shall be measured. Measurements shall then be taken at the other specified frequencies, giving the change in modulation sensitivity, usually expressed in decibels, which shall be within the limits stated in the detail specification.

#### 4.5.22.5 Pulse amplitude modulation

The oscillator shall be connected to the specified load and as shown in figure 33.

A pulse generator, providing a modulating signal of specified waveform and repetition frequency, and which shall not be harmonically related to the oscillator frequency, shall be connected to the modulation input terminal of the oscillator.

Both this signal and the output waveform of the oscillator shall be displayed simultaneously on the oscilloscope, with the peak-to-peak amplitude of the output waveform adjusted to be twice that of the modulating signal, as shown in figure 34.

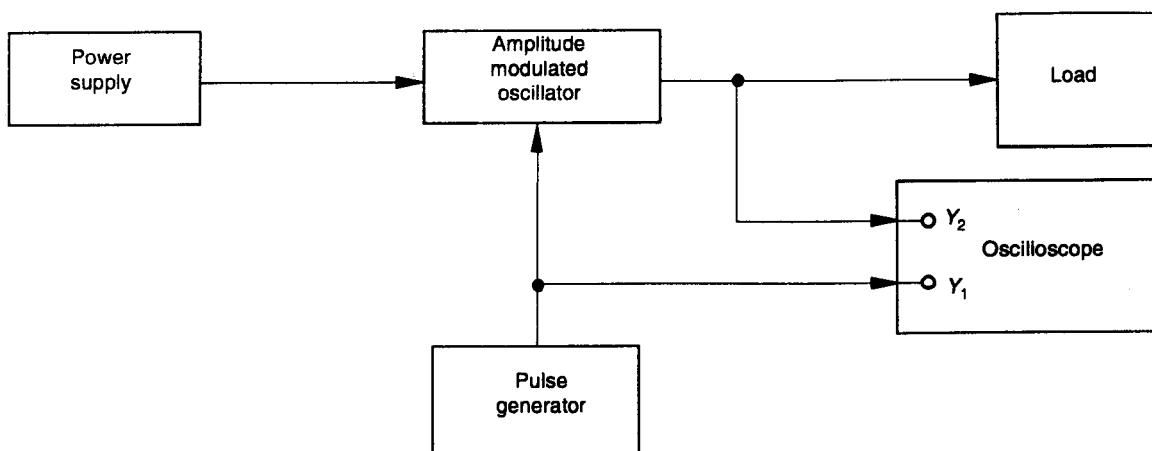


Figure 33 – Test circuit to determine pulse amplitude modulation

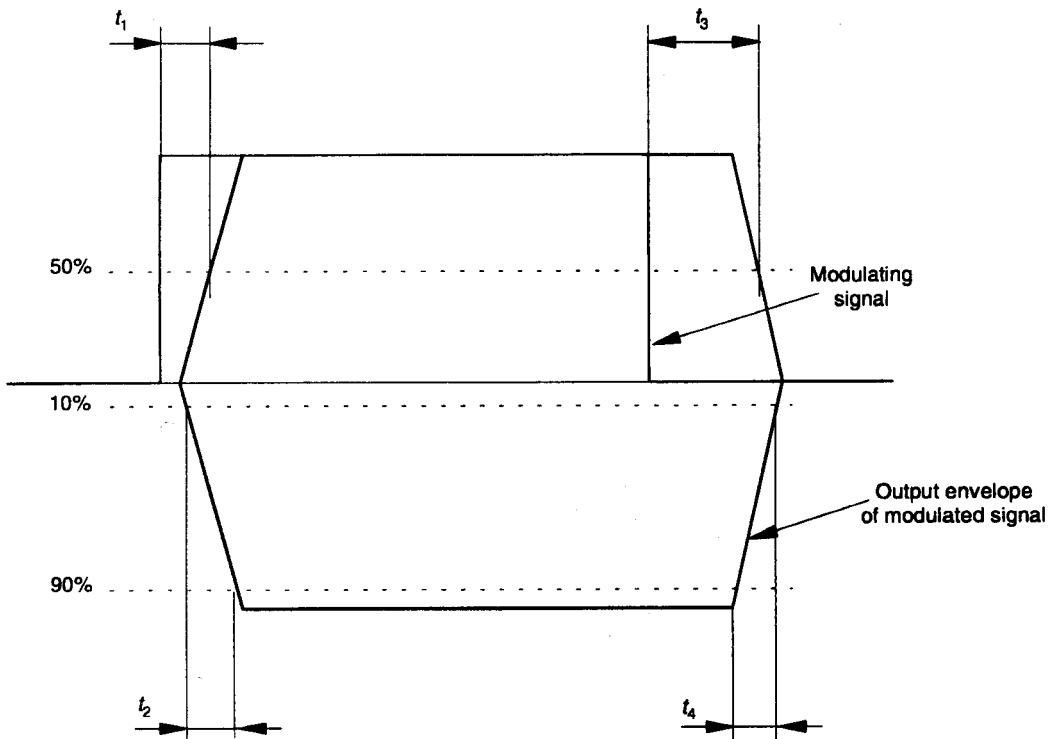


Figure 34 – Pulse modulation characteristic

The following parameters shall be determined and shall be as stated in the detail specification:

- $t_1$  is the turn-on time, the time interval between the 50 % value of the modulating signal and the 50 % value of the output waveform, at the leading edge;
- $t_2$  is the rise time, the time interval between the 10 % and 90 % values of the leading edge of the output waveform (assuming that the modulating signal rise time is negligible);

$t_3$  is the turn-off time, the time interval between the 50 % value of the modulating signal and the 50 % value of the output waveform, at the trailing edge;

$t_4$  is the decay time, the time interval between the 90 % and 10 % values of the trailing edge of the output waveform (assuming that the modulating signal fall time is negligible).

#### 4.5.22.6 Amplitude modulation input impedance

A signal generator providing a modulating signal at the specified frequency shall be connected to the external modulation terminal of the oscillator and to a resistance box through a shielded transformer, as shown in figure 35. The resistance box shall be non-reactive at the specified measurement frequency.

An oscilloscope (or suitable a.c. voltmeter) shall be connected so as to measure either the signal level across the resistance box ( $V_1$ ) or the input level of the modulating signal to the oscillator ( $V_2$ ).

The signal generator shall be adjusted so that the voltage level of the modulating signal at the input to the oscillator is at the specified level.

The modulation input impedance shall be calculated as:

$$Z = \frac{V_2}{V_1} R$$

and shall be as stated in the detail specification.

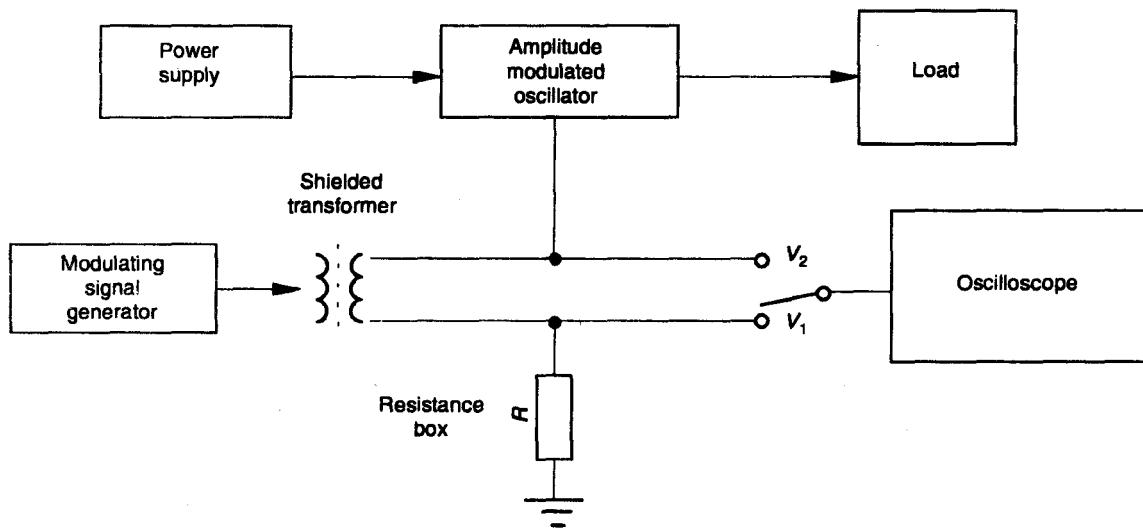


Figure 35 – Test circuit for the determination of modulation input impedance

#### 4.5.22.7 Incidental frequency modulation on an amplitude modulation signal

The amplitude modulation shall be adjusted to the specified index, as described in 4.5.22.1. The resultant frequency modulation deviation shall then be measured, as described in 4.5.23.1. The magnitude of the deviation of the incidental frequency modulation of the amplitude modulated signal shall be within the limits stated in the detail specification. The limiting action of the frequency multiplier(s) will remove most of the amplitude modulation from the signal. However, care shall be taken to ensure that the residual a.m. is insufficient to affect the accuracy of the frequency modulation meter.

#### 4.5.23 Frequency modulation characteristics

##### 4.5.23.1 Frequency modulation deviation

###### Test A

This test shall be used for a peak frequency deviation greater than 100 Hz.

The oscillator shall be connected to the specified load, as shown in figure 36, with a modulating signal of specified frequency applied to its modulation input terminal.

The peak frequency deviation of the output signal shall be measured using an f.m. modulation (or deviation) meter, and shall be within the limits as stated in the detail specification.

When measuring very high frequency signals having a low peak frequency deviation, it may be necessary to use a local oscillator which is phase locked to a source having a low incidental f.m. content (for example a crystal oscillator), in order to reduce its f.m. noise deviation.

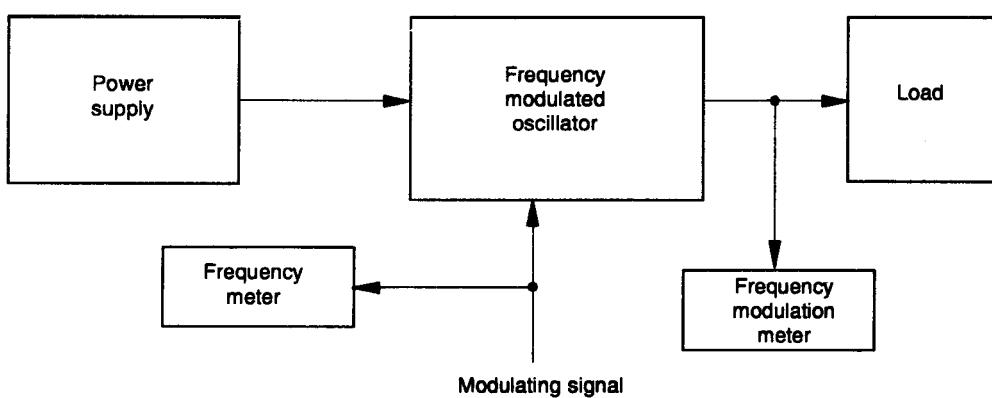


Figure 36 – Test circuit for the measurement of f.m. deviation

NOTE – Frequency modulation index  $\beta = \frac{\Delta f}{f_m}$

where

$\Delta f$  is the actual peak frequency deviation;

$f_m$  is the frequency of the modulating signal.

###### Test B

This test shall be used for a peak frequency deviation smaller than 100 Hz.

The oscillator shall be connected to the specified load, as shown in figure 36, with the addition of a frequency multiplier before the f.m. modulation meter (see note 2).

A modulating signal of specified frequency shall be applied to the modulation input terminal of the oscillator and the peak frequency of the output signal measured through the frequency multiplier using an f.m. modulation (or deviation) meter.

Hence:

$$\text{actual peak deviation} = \frac{\text{measured peak deviation}}{\text{multiplication factor}}$$

The value obtained shall be within the limits stated in the detail specification.

When using this test method it shall be necessary to observe the following precautions:

- when measuring very high frequency signals having a low peak frequency deviation, it may be necessary to use a local oscillator which is phase locked to a source having a low incidental f.m. content (for example a crystal oscillator), in order to reduce its f.m. noise deviation;
- most oscillators are in some measure susceptible to ripple on the supply voltage; when measuring signals having a small frequency modulation index, great care shall be taken to ensure that supply voltage variations do not affect the measurement of peak frequency deviation.

NOTE 1 – Frequency modulation index  $\beta = \frac{\Delta f}{f_m}$

where

$\Delta f$  is the actual peak frequency deviation;

$f_m$  is the frequency of the modulating signal.

NOTE 2 – It may be necessary to use a mixer, before and/or after frequency multiplication, to down-convert the signal to bring it within the range of the frequency modulation meter.

#### 4.5.23.2 Frequency modulation sensitivity

The oscillator shall be connected to the specified load, as shown in figure 37. A signal generator providing a modulating signal at the specified frequency shall be connected to the modulation input terminal of the oscillator and its output set to the specified amplitude as measured by the oscilloscope or r.f. voltmeter. The specified modulation input level shall be such that the specified maximum permissible peak deviation of the oscillator is not exceeded. The peak frequency deviation of the output signal shall be measured as described in 4.5.23.1, tests A or B, as appropriate.

The frequency modulation sensitivity is defined as:

$$\frac{\text{peak-to-peak frequency deviation}}{\text{peak-to-peak modulating signal voltage}}$$

Its value shall be within the limits stated in the detail specification.

NOTE – This method may be used to determine the immunity of an oscillator to power supply line ripple etc., by superimposing the modulating signal on the d.c. supply voltage.

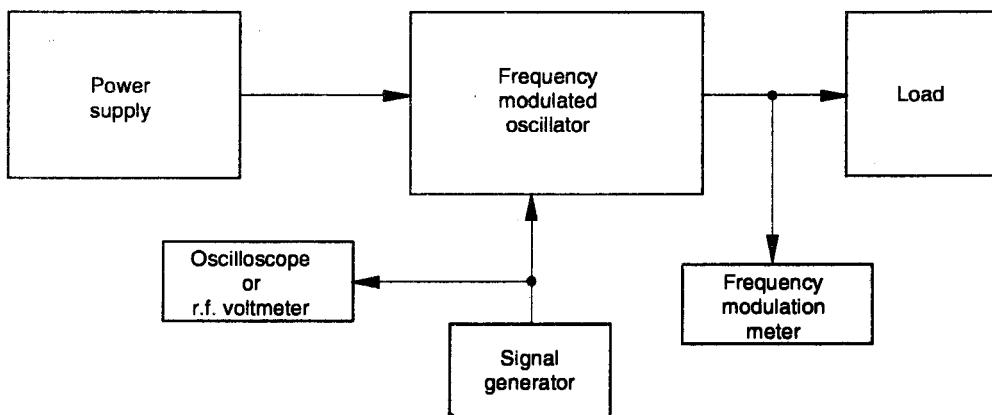


Figure 37 – Test circuit for the measurement of f.m. sensitivity

#### 4.5.23.3 Frequency modulation distortion (non-linearity)

##### Test A (static test)

The oscillator shall be connected to the specified load, as shown in figure 38a, with a variable voltage d.c. power supply connected to the modulation input terminal. Measurements of the oscillator output frequency at the specified d.c. modulation voltages shall be made. A graph of output frequency against control voltage shall be plotted and hence the linearity of the frequency modulation deviation determined. This shall be within the limits stated in the detail specification.

##### Test B (dynamic test)

The oscillator shall be connected to the specified load, as shown in figure 38b.

A sinusoidal signal, at the specified frequency and at a voltage level such as to produce the specified modulation frequency deviation (see 4.5.23.1, tests A or B, as appropriate), shall be applied to the external modulation terminal of the oscillator.

The distortion of the output signal from the modulation detector (in modulation meter) shall be measured with a distortion meter. The distortion shall be within the limits stated in the detail specification.

When using this test method, it shall be necessary to observe the following precautions:

- if the harmonic content of the modulating signal is significant, the results obtained shall be corrected, or filtering may be added to the modulating signal to reduce the harmonic content;
- the distortion introduced by the detector of the modulation meter shall be low compared with that of the oscillator under test.

#### 4.5.23.4 Frequency modulation frequency response

Using the procedures described in 4.5.23.2 with a sinusoidal modulating signal applied, the frequency modulation sensitivity at a specified reference frequency shall be measured. Measurements shall be made at other specified frequencies and the change in modulation sensitivity, usually expressed in decibels, determined. This change shall be within the limits stated in the detail specification.

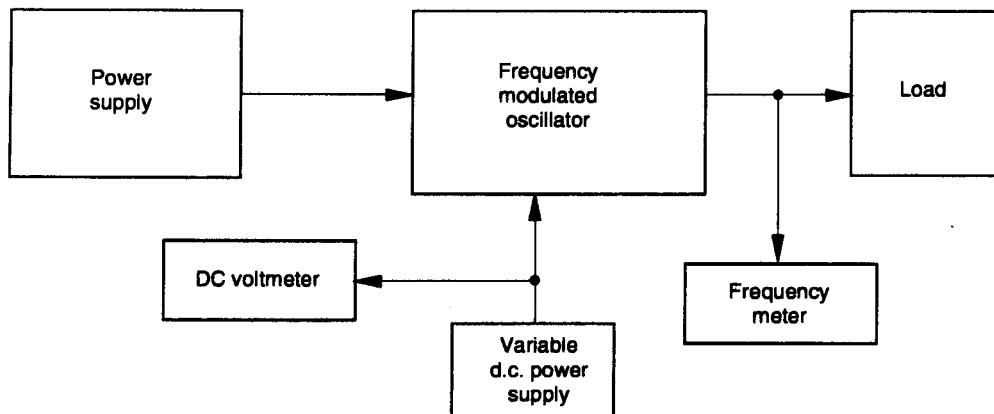


Figure 38a – Static test

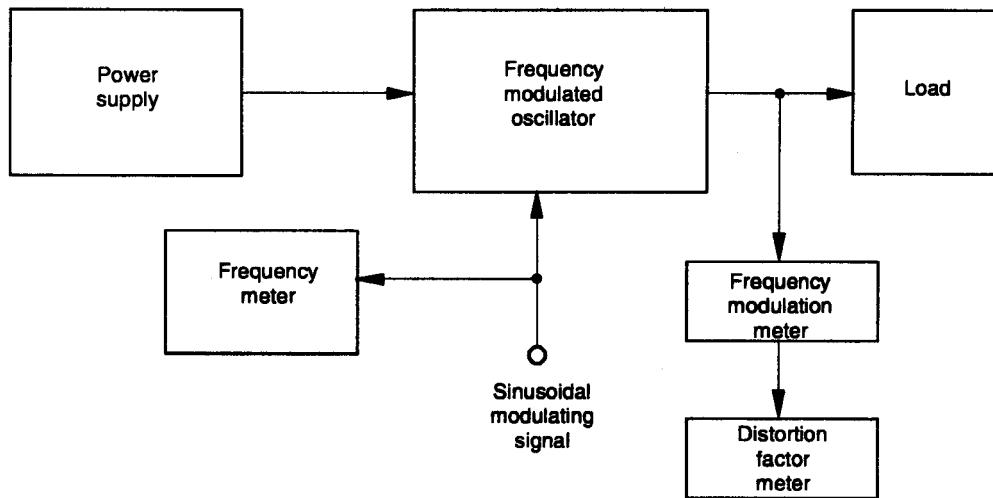


Figure 38b – Dynamic test

Figure 38 – Test circuit for the measurement of frequency modulation distortion

#### 4.5.23.5 Frequency modulation input impedance

This test shall be performed exactly as described in 4.5.22.6.

The resultant impedance shall be as specified in the detail specification.

#### 4.5.24 Spurious response

The spurious response(s) shall be measured using the procedures exactly as described in 4.5.15, except that the measuring system shall be screened against any high level signals in the environment of the oscillator under test.

NOTE – Spurious response(s) are, by definition, not harmonically related to the fundamental frequency and so it is difficult to differentiate between oscillator-generated spurious signals and those which may be picked up from the operating environment. This may be checked by removing the supply voltage from the oscillator.

#### 4.5.25 Phase noise

##### 4.5.25.1 General

Phase noise gives rise to a sideband distribution that consists of symmetrical pairs whose relative amplitude, compared to the carrier, is equal to half the peak phase deviation of that component in radians.

For the measurement of phase noise, synchronous signals are compared by means of a phase detector. The output of the phase detector is the instantaneous voltage analogue of the phase noise contribution. For the phase detector to be held to zero output, except for the phase noise contributions, it is essential that the oscillator under test (oscillator 2 in figure 39) be kept in quadrature with the reference oscillator. This is achieved by using a d.c. amplifier to sense a zero phase detector output and hence drive the test oscillator to phase quadrature.

The output phase noise is monitored with a low frequency wave analyzer. The noise measured by the wave analyzer will be r.m.s. noise (it may be necessary to perform a conversion for average/r.m.s.) in both sidebands; this may be converted to a single-sideband phase noise by subtracting 6 dB.

Ideally, the reference oscillator (oscillator 1 in figure 39) should have a very low noise contribution. It frequently occurs that both oscillators are of similar type; if this is so, it may be assumed that both oscillators have equal noise contributions, that is the signal-to-phase noise ratio will be degraded by 3 dB for similar oscillators. An appropriate allowance should be made when calculating the results.

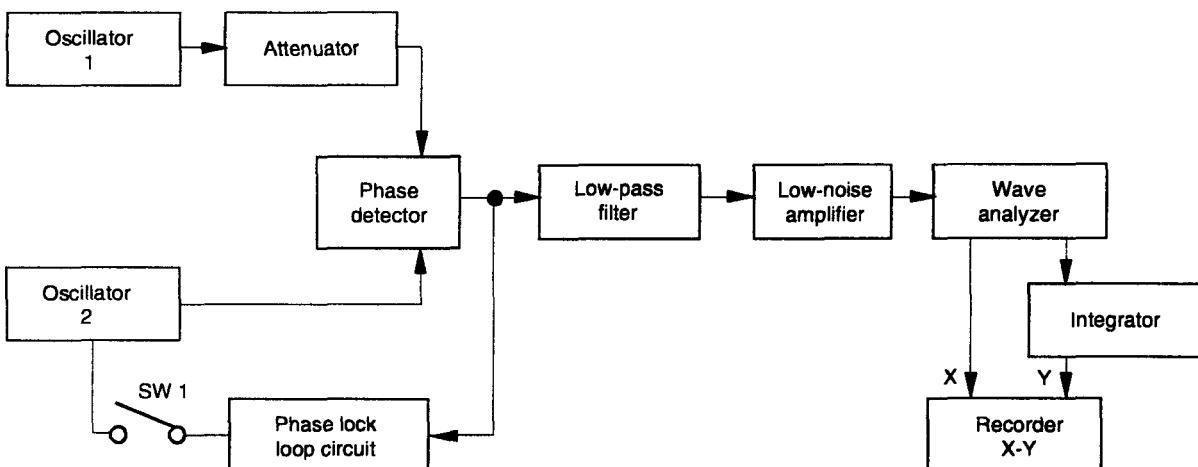


Figure 39 – Test circuit for the measurement of single-sideband phase noise

#### 4.5.25.2 Procedure

The circuit shall be connected as shown in figure 39. The feed-back loop from the phase detector shall be arranged such that oscillator 1 and oscillator 2 may be phase-locked in quadrature. The wave analyzer shall be set to the specified resolution bandwidth (frequency 1 Hz) and the integrator time constant to 1 s, unless otherwise stated in the detail specification.

Switch 1 shall be opened and a difference frequency will be established between oscillator 1 and oscillator 2. The wave analyzer shall be adjusted to the difference frequency and the scale of the X-Y recorder calibrated by means of the attenuator in the region -60 dB to -80 dB (high attenuation to prevent overloading of the low-noise amplifier).

Switch 1 shall then be closed. Oscillators 1 and 2 are phase locked in quadrature. The attenuator shall be set to -10 dB, unless otherwise stated in the detail specification, and the wave analyzer tracked in frequency over the specified range of offset frequencies over which the phase noise is to be measured.

#### 4.5.25.3 Precautions

The response time of the frequency-control loop shall be very long compared with the period of the lowest sideband noise to be measured. For example, a 10 s response time (or 0.1 Hz cut-off frequency) would be indicated in order to measure phase noise sidebands at 1 Hz. Within the pass-band of the locking loop, the output signal is proportional to frequency noise; far outside the locking-loop pass-band, the output signal is proportional to phase noise, but in the transition region, the situation is somewhat complicated.

General precautions pertaining to the use of narrow-band tuned detectors shall be followed; in particular, the tuning rate (Hz/s) shall be small compared with the detector bandwidth (Hz) and the post-detector integration time shall be long compared with the inverse detector bandwidth.

For example, with a 10 Hz detector pass-band, the tuning (or slew) rate should be no greater than 1 Hz/s, and an integration time of at least 1 s should be used.

NOTE 1 – The limit of resolution of this measurement system is determined by the minimum bandwidth of the wave analyzer. In this case, spectral components having a Fourier frequency lower than the analyzer bandwidth may not be measured.

NOTE 2 – It is assumed that the noise contribution from the phase lock loop is small compared with the oscillator contribution. An alternative circuit arrangement is to manufacture the two oscillators with, for example, a 25 kHz frequency separation and then to examine (with the wave analyzer) the noise distribution around the 25 kHz output from a mixer, which should be used in place of the phase detector. In this arrangement, a band-pass filter (centred on the difference frequency) may be used instead of the low-pass filter. The disadvantage of this system is that it has an inherently lower stability and, in general, it will not be possible to use such low resolution bandwidths.

#### 4.5.26 Phase noise – vibration

Using the procedure described in 4.5.25, the phase noise shall be measured with the oscillator operating whilst being subjected to vibration, as described in 4.6.7.2 (sinusoidal) or 4.6.7.3 (random).

The phase noise (vibration) shall be as specified in the detail specification.

#### 4.5.27 Phase noise – acoustic

Using the procedure described in 4.5.25, the phase noise shall be measured with the oscillator operating whilst being subjected to acoustic noise, as required by 4.6.12.

#### 4.5.28 Noise pedestal

##### 4.5.28.1 General

The noise pedestal refers to the relative level of the oscillator frequency and the far-out noise level from the oscillator.

The graph in figure 40 shows a typical spectrum as obtained from a crystal oscillator as displayed on a spectrum analyzer. Subclause 4.5.25 relates to the measurement of the noise contribution close to the oscillator frequency, while this test relates to the far-out contribution, usually expressed in decibels, below the oscillator frequency.

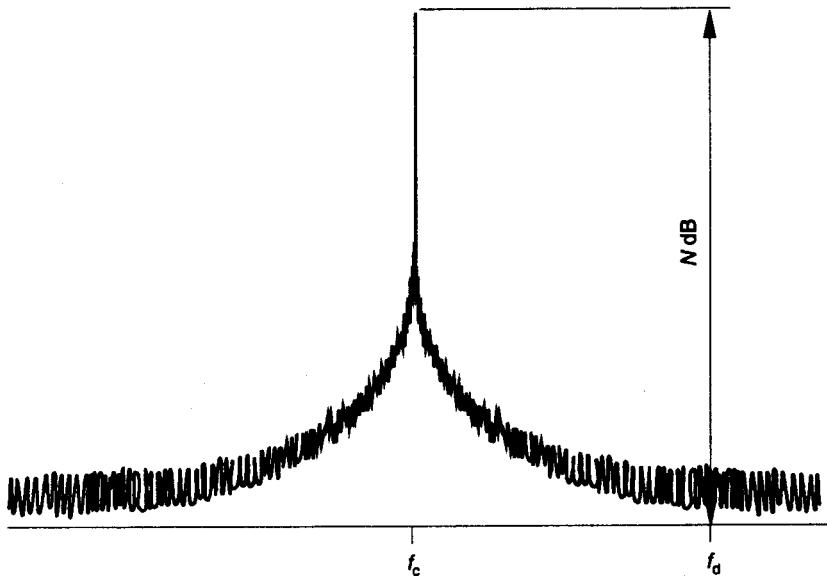


Figure 40 – Typical noise pedestal spectrum

##### 4.5.28.2 Procedure

The oscillator shall be connected to the specified load and spectrum analyzer of specified resolution bandwidth, as shown in figure 21.

From the output spectrum of the oscillator displayed on the spectrum analyzer, the noise pedestal shall be measured from the noise base line where it reaches asymptotic level, or at a specified frequency ( $f_d$ ).

The measurement frequency ( $f_d$ ) or separation from the oscillator frequency ( $f_c - f_d$ ), if a specific frequency offset is relevant, shall be specified in the detail specification.

NOTE – The mean level of the noise should be taken as the base line. This may be easily assessed if the spectrum analyzer incorporates a video filter which may be set for a long time constant, for example to a 10 Hz low-pass bandwidth.

#### 4.5.28.3 Precautions

The following precautions shall be observed:

- care shall be taken to ensure that the noise contribution of the spectrum analyzer does not degrade the measurement of noise pedestal; this may be checked by changing the input attenuator setting of the spectrum analyzer. This should not change the value of  $N$  (see figure 40), but rather reduce both the oscillator frequency level and the level of the far out noise. Spectrum analyzer noise will limit the applicability of this test to oscillators having a noise pedestal of about 70 dB to 90 dB (depending on the spectrum analyzer) or worse;
- should the noise pedestal be below the threshold level of the spectrum analyzer, the method described in 4.5.25 may be used to obtain an estimate of the noise pedestal; this is perfectly valid because, at low levels, the major contribution to the overall noise results from frequency or phase effects.

#### 4.5.29 Spectral purity

##### 4.5.29.1 General

Out-band noise refers to the relative level of the noise of frequencies far from the oscillator frequency, including discrete harmonic or spurious single frequency tones, to the level of the oscillator frequency.

Subclause 4.5.25 deals with the measurement of phase noise in the enhancement region near (within several bandwidths) the oscillator frequency, while this subclause refers to the flat additive noise region extending from several kilohertz to as much as several megahertz away from the oscillator frequency.

##### 4.5.29.2 Procedure

The oscillator shall be connected as shown in figure 21 and the spectrum analyzer adjusted to display the specified frequency range. The level of the noise pedestal may be determined directly from the spectrum analyzer display (in decibels), with appropriate correction for the analyzer bandwidth (that is 10 dB per decade bandwidth) in order to reduce the data to a 1 Hz basis.

##### 4.5.29.3 Precautions

Care shall be taken to ensure that the noise contribution of the spectrum analyzer does not degrade the measurement. This may be checked by inserting a variable attenuator between the oscillator and the spectrum analyzer, and ensuring that both carrier and noise levels respond equally to attenuator setting.

In many cases, the signal-to-wideband noise ratio of crystal controlled oscillators will greatly exceed the dynamic range of available spectrum analyzers; in this case, it will be necessary to use a narrow-band elimination filter to attenuate the carrier to some known amount (that is 80 dB or 90 dB) in order to avoid saturation of the analyzer. Alternatively, some demodulation scheme may be used, such as the narrow-band phase locked loop of 4.5.25, to remove the carrier effectively.

NOTE – Since the additive noise level from a crystal controlled oscillator may be comparable to the thermal noise generated by the load impedance itself, great care is recommended in the selection of any amplifier or signal processing equipment used in its measurement.

#### 4.5.30 Incidental frequency modulation

The oscillator is connected as shown in figure 41 and allowed to stabilize. The frequency discriminator shall provide a linear characteristic over a sufficiently wide band to prevent distortion of base-band spectral components in the specified frequency range. The incidental f.m. spectrum will be obtained directly on the X – Y recorder and shall be within the limits stated in the detail specification.

If it is specified to determine the total f.m. signal in a particular base-band region, a suitable band-pass filter and r.m.s. voltmeter may be substituted for the wave analyzer and X - Y recorder. In either case, it shall be necessary to determine the discriminator characteristic (volts/hertz deviation) in order to establish the calibration system.

It shall be necessary to take into consideration the following precaution.

The incidental f.m. of high-quality crystal controlled oscillators is commonly very small, especially at low base-band frequencies, requiring careful selection of low-noise discriminators and video amplifiers. Post-detection integration time and wave analyzer scanning rate shall be adjusted to be compatible with the wave analyzer bandwidth, in order to ensure accurate measurement of discrete f.m. tones, such as those produced by power supply ripple voltage, etc.

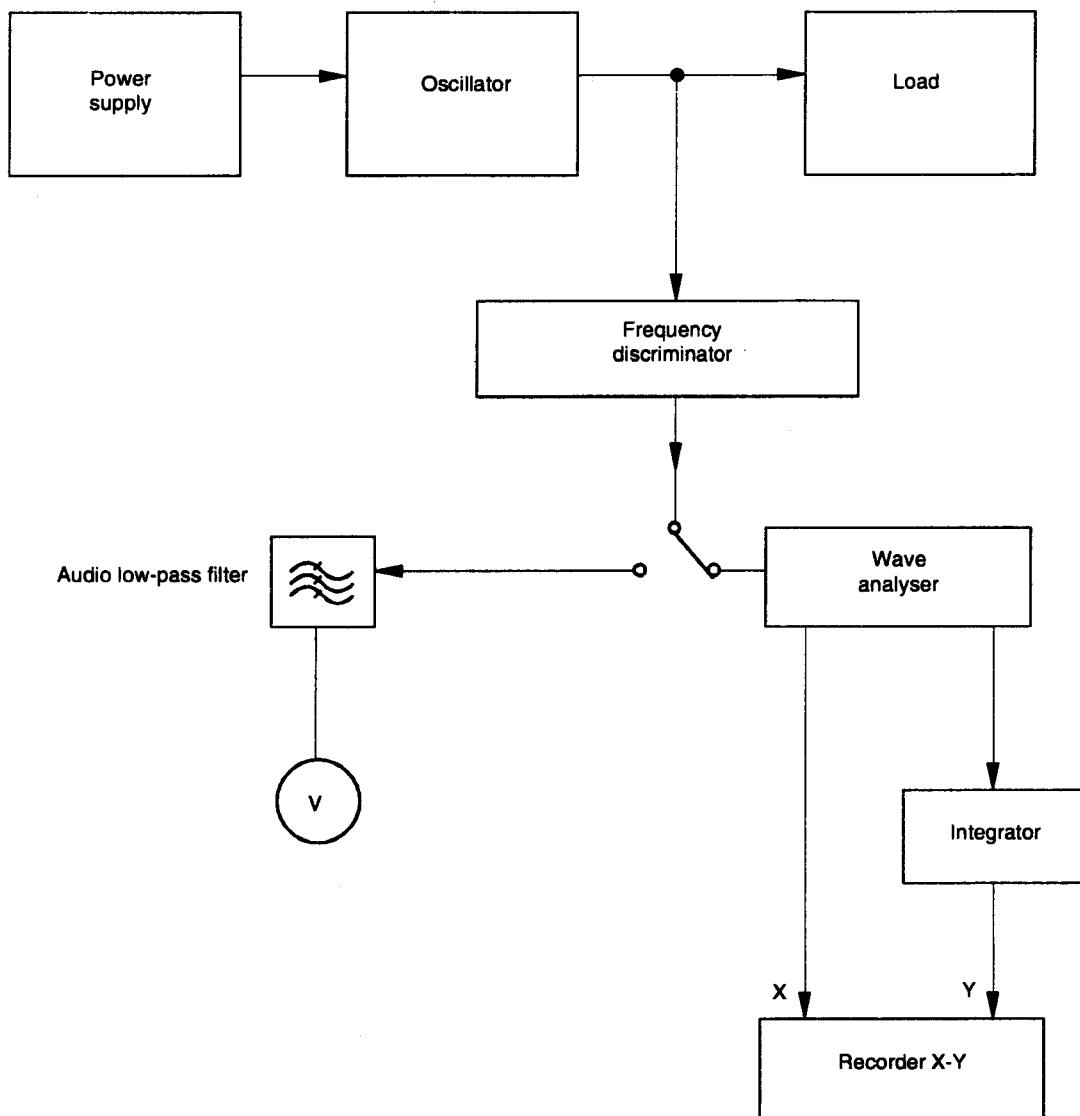


Figure 41 – Test circuit for the measurement of incidental frequency modulation

#### 4.5.31 RMS fractional frequency fluctuations

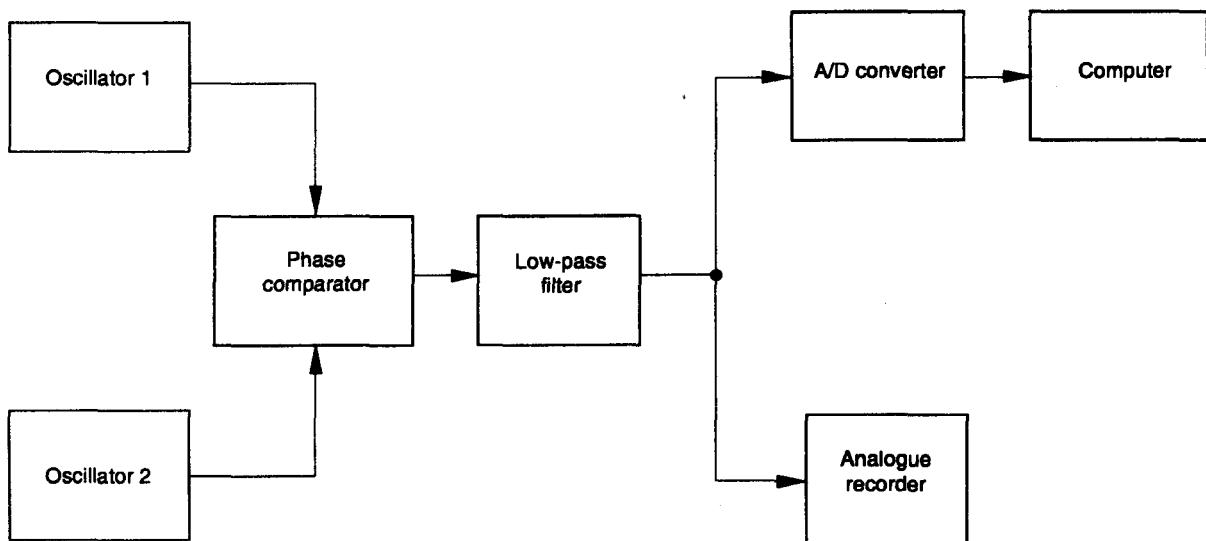
##### 4.5.31.1 Procedure

In principle, time domain stability measurements are made with respect to a reference source having much better stability than the unit under test.

In general practice, however, comparisons are commonly made between two oscillators of similar design, and it is usually assumed that the probability densities and distribution functions of their random noise processes are nearly the same. Since the noise processes combine on a power basis, the fractional frequency fluctuations between the two similar oscillators shall be divided by  $\sqrt{2}$  to arrive at an estimate of the fluctuation due to one of the oscillators alone. This is reflected in the formulae derived for each of the two methods.

##### Method 1 – Two oscillators having exactly the same mean frequency

The two oscillators shall be connected as shown in figure 42.



NOTE – Phase comparators are often sensitive to both phase and amplitude deviations. In order to minimize sensitivity to amplitude, it is normal practice to use a double-balanced mixer as a quadrature detector.

Figure 42 – Test circuit for method 1

In the case of method 1, the phase comparator produces an analogue signal which is directly proportional to the instantaneous phase fluctuations between the two oscillator signals (for Fourier frequencies below the cut-off of the low-pass filter). This signal may be examined by analogue methods (such as continuous strip-chart recorder, r.m.s. voltmeter or spectrum analyzer), or it can be examined by time domain methods using a sampling type A/D converter with a controlled sample averaging time  $\tau$ , and the repetitive sampled measurements stored for analysis by a computer. Using this method, there is no dead time introduced in the measurement system, and the r.m.s. fractional frequency fluctuation is:

$$\frac{\Delta F}{F_0} (\tau)_{\text{rms}} = \frac{1}{4 \pi F_0 \tau} \left[ \frac{1}{(M-1)} \sum_{k=1}^{M-1} \left[ [\varphi(t_k + 2\tau) - \varphi(t_k + \tau)] - [\varphi(t_k + \tau) - \varphi(t_k)] \right]^2 \right]^{1/2}$$

where

$M$  is the number of repetitive measurements;

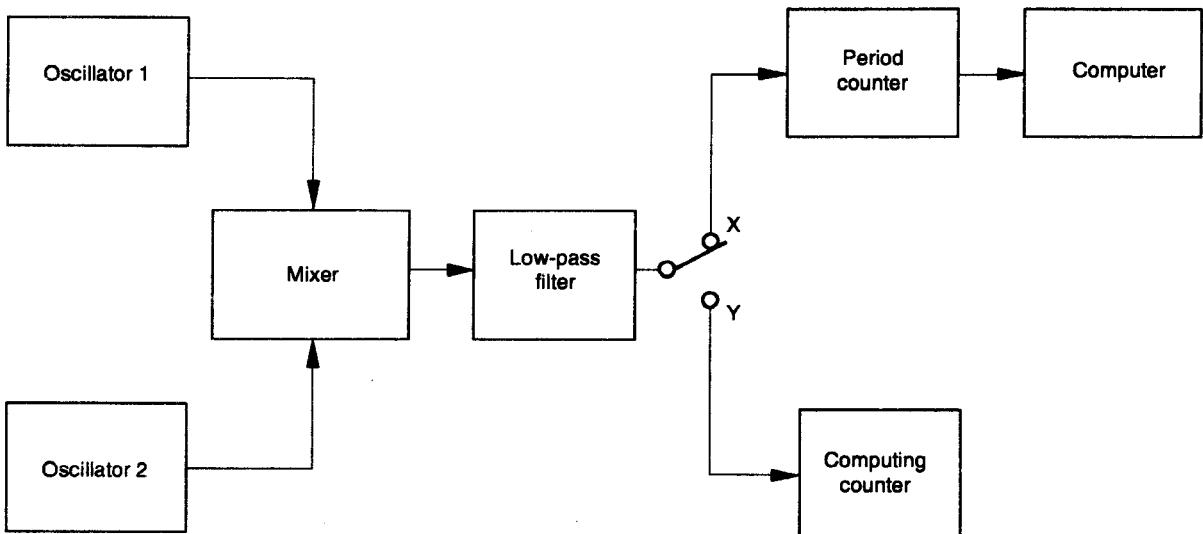
$\tau$  is the sample averaging time.

NOTE – If, in fact, the reference oscillator used has much better stability than the unit under test, then all of the frequency fluctuations can be attributed to the unit under test and the equation above should be multiplied by  $\sqrt{2}$ .

### Method 2 – Two oscillators having slightly different frequencies

The two oscillators shall be connected as shown in figure 43.

In this case, the two oscillators being compared are usually made to be essentially identical, except that one of the controlling crystals is adjusted to a slightly different frequency. Therefore, the output of the mixer will have a sinusoidal waveform whose frequency is the difference between the two oscillator frequencies. This is commonly chosen to be somewhere in the range from 100 Hz to 10 kHz. It is assumed that the small difference in crystal unit adjustment will not significantly influence the random noise characteristics of the oscillator.



NOTE – Position X or Y may be used to obtain the Allan variance and deviation. X allows determination of the standard deviation as well.

Figure 43 – Test circuit for method 2

The specified number of measurements  $M$  of the period of the beat frequency is made, using the specified averaging time  $\tau$  ( $\tau$  should be an integral number of periods of the beat frequency). The interval between successive measurements  $T$  will usually be at least one period of the beat frequency longer than the sample averaging time  $\tau$  and may be two or more periods greater depending upon the beat frequency and the recycling time of the counter-data acquisition system. The fractional frequency fluctuation is:

$$\frac{\Delta F}{F_0} (\tau)_{\text{rms}} = \frac{1}{\sqrt{B_2(r, \mu)}} \times \frac{1}{2 F_0} \left[ \frac{1}{(M-1)} \sum_{k=1}^{M-1} (F_{k+1} - F_k)^2 \right]^{1/2}$$

where

$\tau$  is the sample averaging time;

$B_2(r, \mu)$  is the correction factor for dead time;

$T$  is the sampling period;

$r = \frac{T}{\tau}$  is the ratio of sampling period to sample averaging time;

$F_k, F_{k+1}$  are the successive measurements of the beat frequency averaged for sample time  $\tau$ , as described above.

NOTE – As for method 1 above, if the reference oscillator has much better stability than the unit under test, all of the frequency fluctuations can be attributed to the unit under test and the value above should be multiplied by  $\sqrt{2}$ .

#### 4.5.31.2 Modification of methods 1 and 2

Use of a crystal filter

In special instances (for example if only very short averaging times are of interest), a narrow-band crystal filter may be inserted between the reference oscillator and the mixer or phase comparator, as shown in figure 44. For averaging times  $\tau$  much less than the reciprocal of the filter bandwidth, this modification can remove the noise sidebands from the reference signal, so that only the frequency fluctuations of the unit under test will be observed. To be effective, however, the crystal filter itself shall be free from excess noise, protected from mechanical disturbances and maintained at constant temperature.

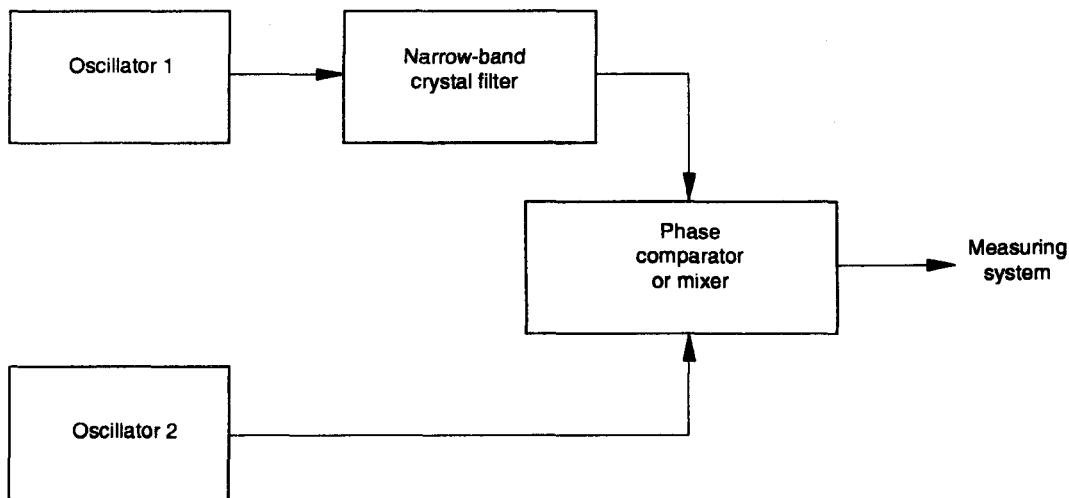


Figure 44 – Circuit modifications for methods 1 and 2

#### 4.5.31.3 Precautions

The short-term frequency stability of an oscillator is a very sensitive measure of the spectral purity and, as such, should be performed under controlled conditions. For high orders of stability, screened enclosures should be used, the recording apparatus being outside the enclosure.

#### 4.5.31.4 Results

The short-term frequency stability of an oscillator shall be given in graphical form. An example is given in figure 45.

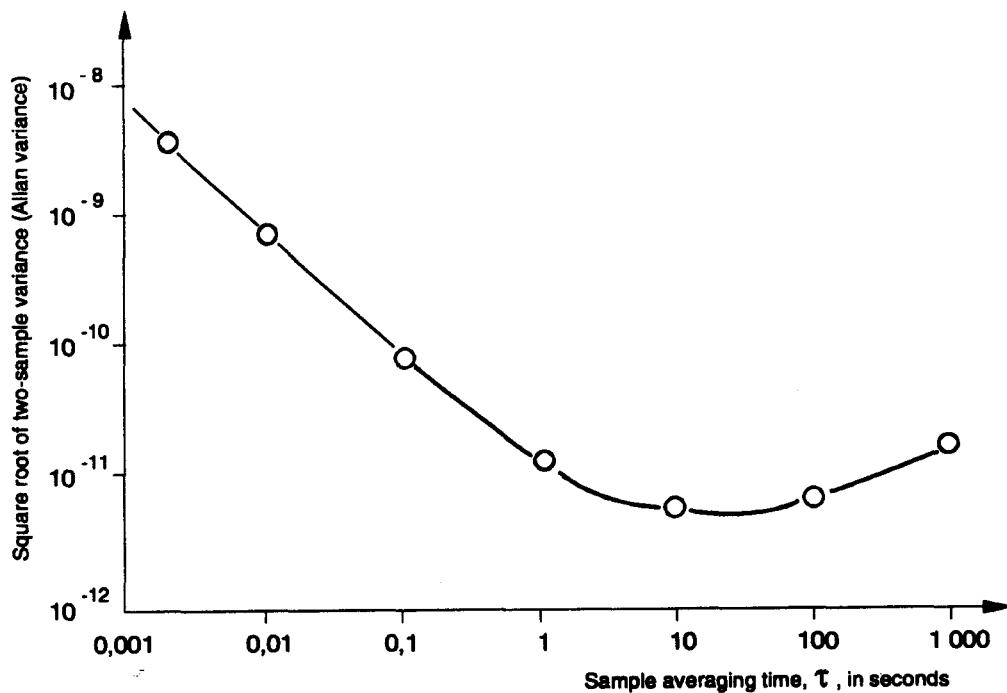
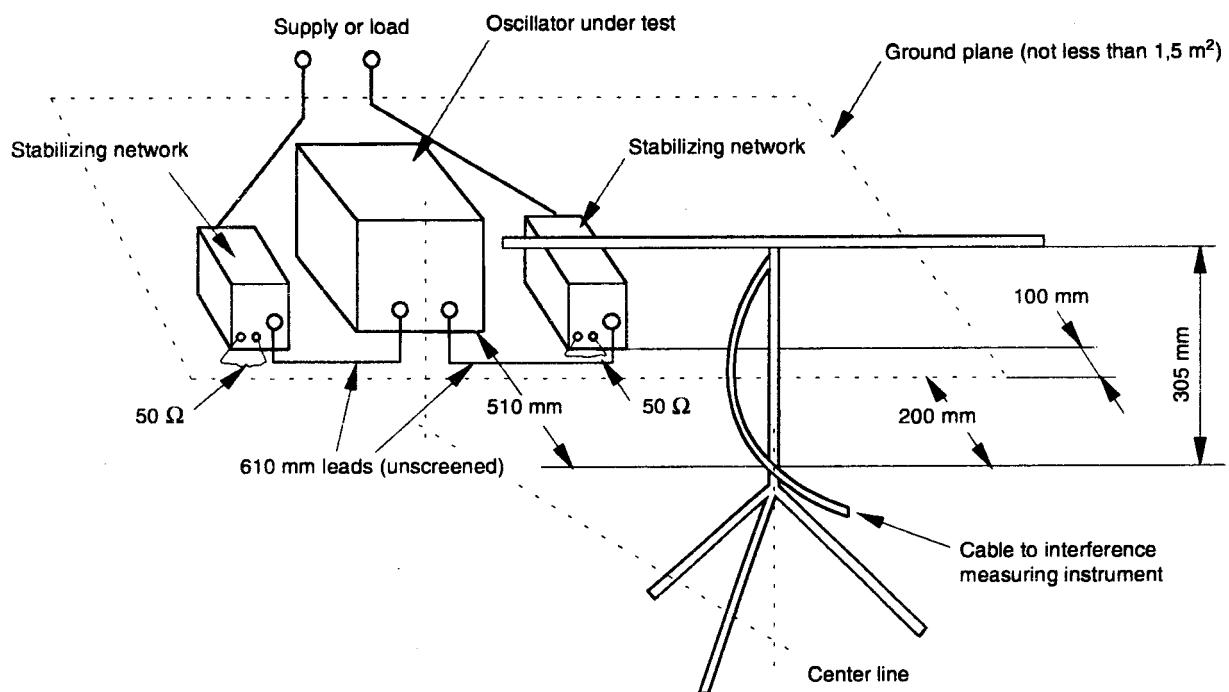


Figure 45 – Time-domain short-term frequency stability of a typical 5 MHz precision oscillator

#### 4.5.32 Electromagnetic interference (radiated)

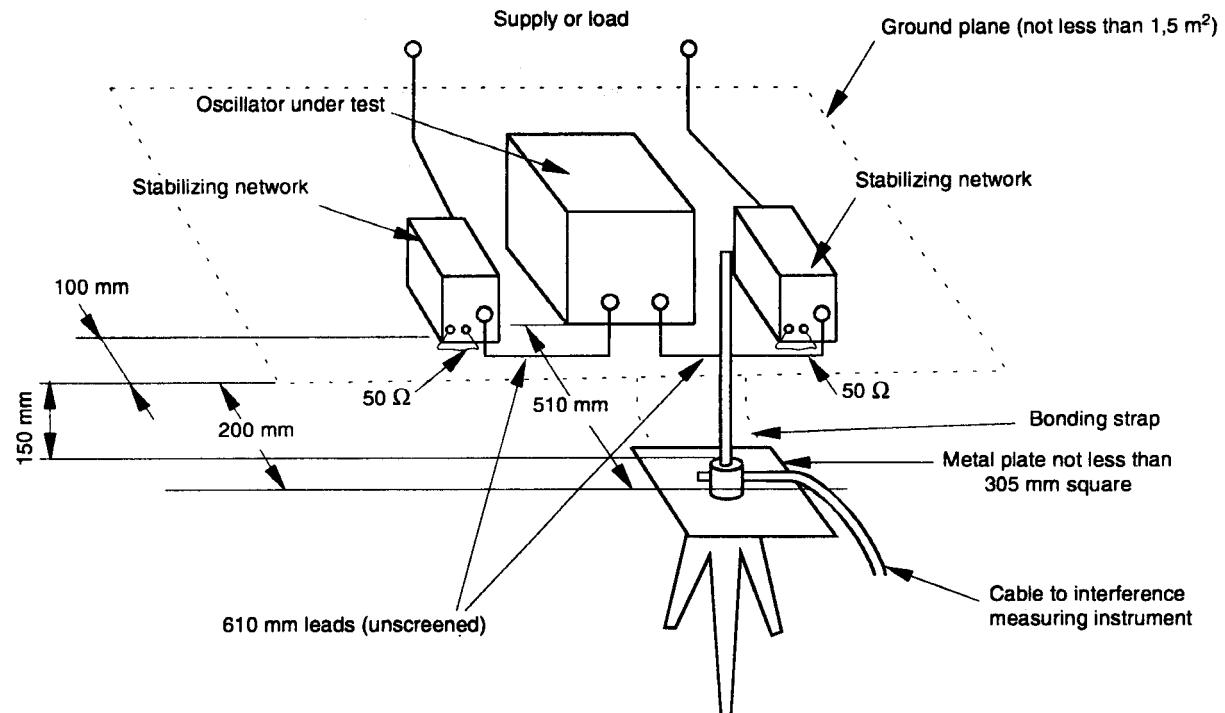
This method shall be used, unless otherwise specified by national regulations.

The test arrangements shall be as described in figures 46a and 46b.



NOTE – Stabilizing network to be bonded to the ground plane.

Figure 46a – Typical arrangement for radiated interference tests, 30 MHz and above



NOTE – Stabilizing network to be bonded to the ground plane.

Figure 46b – Typical arrangement for radiated interference tests, below 30 MHz

Figure 46 – Radiated interference tests

#### 4.5.32.1 Test conditions

For tests of radiated interference, it is essential that the test should be made in a screened room having dimensions not less than 2,4 m high, 2,1 m wide, and 4,6 m long.

Ideally, the tests for conducted interference should be made in a screened room having adequate filters in all incoming supply lines. If this is impracticable, precautions should be taken to ensure that the results are not affected by noise voltages and fields other than those due to the oscillator under test. This will involve the use of additional filters in the supply and/or load circuits.

The oscillator under test should be mounted on the ground plane. The ground plane shall be bonded to the screened room at points not more than 0,9 m apart, and at the ends of the ground plane.

The leads from the oscillator under test to the line impedance stabilizing network shall be 610 mm in length, and shall be screened or unscreened, as shown in the appropriate figure. The stabilizing networks in the lines not being measured shall be terminated by  $50 \Omega$  non-reactive resistors.

The impedance characteristics of the stabilizing network shall be within the limits of figure 47. One practical method of attaining this impedance is shown in figure 48.

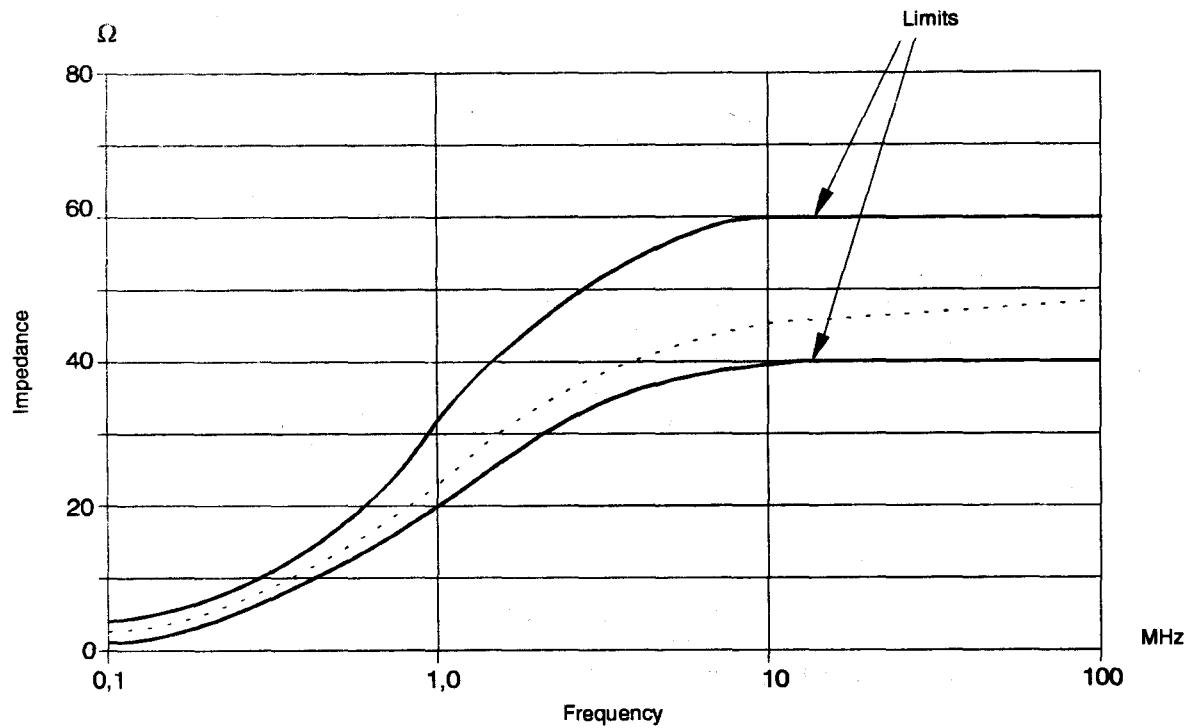
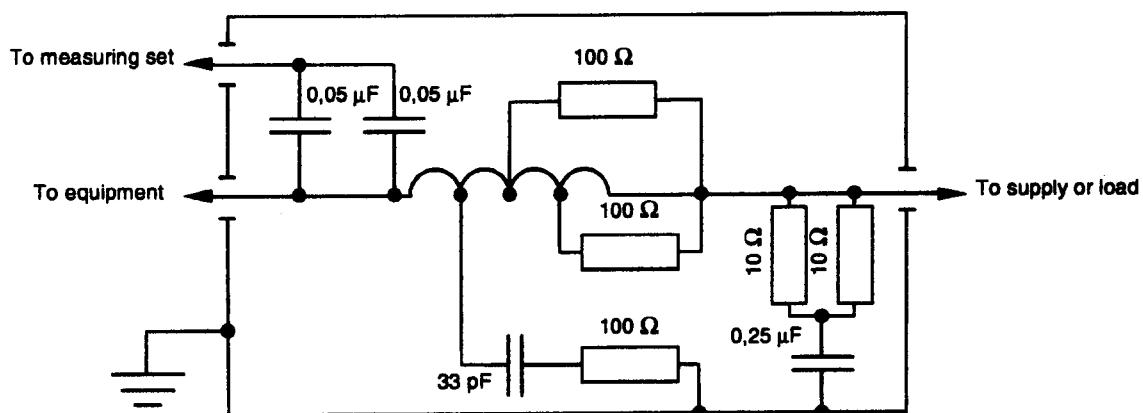


Figure 47 – Characteristics of line impedance of stabilizing network



Coil characteristics:

5  $\mu$ H, 10 turns, 5,89 mm (0,232 in) 4 SWG<sup>1</sup>) wound on 51,0 mm (2 in) diameter former.

Figure 48 – Circuit diagram of line impedance of stabilizing network

#### 4.5.32.2 Procedure

The oscillator shall be set up in a screened room and with a measuring system as described above.

The measurements shall be made under the load conditions producing the worst operating conditions from the point of view of radio interference.

A vertical rod aerial 1 016 mm  $\pm$  25 mm long shall be used at frequencies below 30 MHz. It shall be located at the point where maximum interference is obtained when it is moved along a line parallel to the front edge of the ground plane. At 30 MHz and above, a horizontal dipole aerial shall be used; over the frequency range 30 MHz to 50 MHz, a 50 MHz dipole shall be used and above 50 MHz a resonant dipole shall be used. It shall be placed parallel to the front edge of the ground plane. Its height shall be 305 mm  $\pm$  25 mm above the level of the ground plane and its centre shall be adjacent to the geometrical centre of the unit under test. The rod or the dipole aerial shall be located 508 mm from the nearest point on the surface of the oscillator under test. When the length of the dipole is less than that of the test layout, it shall be moved parallel to the edge of the ground plane to the point of maximum response.

#### 4.5.32.3 Measuring sets

Measuring sets having facilities for the measurement of peak values and having bandwidths within the limits shown in table 1 are preferred for measurements specified in this standard. Measuring sets having other bandwidths are acceptable, provided suitable correlation factors are used.

1) British standard wire gauge.

Table 1 – Measuring sets bandwidths

Frequency range MHz	Bandwidth limits, at -6 dB
0,05 to 0,15	200 Hz ± 100 Hz
0,15 to 30	9 kHz ± 1 kHz
30 to 300	150 kHz ± 50 kHz
300 to 1 000	150 kHz ± 50 kHz

All voltages measured shall be referred to 50 Ω.

If the input impedance of the measuring set differs from this value, a suitable matching network shall be used and the appropriate correction factor applied.

When a measuring set has a quasi-peak voltmeter only, it will need to be modified to read peak voltages.

As the impulse bandwidth of measuring sets normally differs from 1 kHz, an appropriate correction factor shall be applied on a linear basis.

In all cases, the measuring set shall be tuned for a maximum response to the interfering signal.

## 4.6 Mechanical and environmental test procedures

### 4.6.1 Robustness of terminations (destructive)

#### 4.6.1.1 Tensile and thrust tests on terminations

The tests shall be performed in accordance with test Ua<sub>1</sub> (tensile) and test Ua<sub>2</sub> (thrust) of IEC 60068-2-21.

Unless otherwise stated in the detail specification, the values of tensile force shall be as given in table 2 below and the values of thrust force shall be as given in table 3 below.

Table 2 – Tensile force

Nominal cross-sectional area <sup>1)</sup> mm <sup>2</sup>	Corresponding diameter for circular-section wires mm	Force with tolerance of ±10 % N
0,1 < S ≤ 0,2	0,35 < d ≤ 0,5	5
0,2 < S ≤ 0,5	0,5 < d ≤ 0,8	10
0,5 < S ≤ 1,2	0,8 < d ≤ 1,25	20

1) For circular-section wires, strips or pins:  
the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the relevant specification.  
For standard wires:  
the nominal cross-sectional area is obtained by taking the sum of the cross-sectional areas of the individual strands of the conductor specified in the relevant specification.

Table 3 – Thrust force

Nominal cross-sectional area <sup>1)</sup> mm <sup>2</sup>	Corresponding diameter for circular-section wires mm	Force with tolerance of $\pm 10\%$ N
$0,1 < S \leq 0,2$	$0,35 < d \leq 0,5$	1
$0,2 < S \leq 0,5$	$0,5 < d \leq 0,8$	2
$0,5 < S \leq 1,2$	$0,8 < d \leq 1,25$	4

1) For circular-section wires, strips or pins:  
the nominal cross-sectional area is equal to the value calculated from the nominal dimension(s) given in the relevant specification.

#### 4.6.1.2 Flexibility of wire terminations

The test shall be performed in accordance with test Ub (bending) of IEC 60068-2-21.

Unless otherwise stated in the detail specification, the load shall be so restricted that the bend starts  $2,5 \text{ mm} \pm 0,5 \text{ mm}$  from the body of the crystal oscillator, the number of bends shall be three, and the loading mass and the values of bending force shall be as given in table 4.

Table 4 – Bending force

Section modulus mm <sup>3</sup>	Diameter of corresponding round leads mm	Force with tolerance of $\pm 10\%$ N
$4,2 \times 10^{-3} < Z_x \leq 1,2 \times 10^{-2}$	$0,35 < d \leq 0,5$	2,5
$1,2 \times 10^{-2} < Z_x \leq 0,5 \times 10^{-1}$	$0,5 < d \leq 0,8$	5
$0,5 \times 10^{-1} < Z_x \leq 1,9 \times 10^{-1}$	$0,8 < d \leq 1,25$	10

NOTE 1 – For round terminations, the section modulus is given by the following formula:

$$Z_x = \frac{\pi d^3}{32}$$

where

$d$  is the lead diameter;

$Z_x$  is the section modulus.

For strip terminations, the section modulus is given by the following formula:

$$Z_x = \frac{ba^2}{6}$$

where

$a$  is the thickness of the rectangular strip perpendicular to bending axis;

$b$  is the other dimension of the rectangular strip;

$Z_x$  is the section modulus.

NOTE 2 – The section modulus is defined in 3-21 of ISO 31-3 and the derivation of the above formulae can be found in standard textbooks on mechanical engineering.

#### 4.6.1.3 Torque test on mounting studs

The test shall be performed in accordance with test Ud (torque) of IEC 60068-2-21.

Unless otherwise stated in the detail specification, the value of torque force to be applied is given in table 5.

**Table 5 – Torque force**

Nominal thread diameter mm	2,6	3,0	3,5	4,0	5,0	6,0
Torque Nm Severity 2	0,2	0,25	0,4	0,6	1,0	1,25

#### **4.6.2 Sealing tests (non-destructive)**

##### **4.6.2.1 Gross leak test**

This test shall be performed in accordance with the procedure specified in test method 1 or 2 of test Qc of IEC 60068-2-17.

###### **Method 1**

The liquid shall be degassed water and the pressure of air above the water shall be reduced to 8,5 kPa (85 mbar) or less. It shall not be necessary to drain or remove the specimen from the water before breaking the vacuum.

###### **Method 2**

The liquid shall be maintained at  $125^{\circ}\text{C} \pm 5^{\circ}\text{C}$ . The immersion time shall be 30 s, unless otherwise specified in the relevant detail specification.

During the test there shall be no evidence of leakage of gas or air from the inside of the crystal oscillator. The continuous formation of bubbles shall be evidence of leakage.

##### **4.6.2.2 Fine leak test**

The test shall be performed in accordance with 6.4, test method 1 of test Qk of IEC 60068-2-17. Unless otherwise stated in the detail specification, the pressure in the pressure vessel shall be 200 kPa (2 bar).

The maximum leak rate shall not exceed the value specified in 2.3.5, unless otherwise stated in the detail specification.

#### **4.6.3 Soldering (solderability and resistance to soldering heat) (destructive)**

##### **4.6.3.1 Solderability**

###### **Test A (lead terminations)**

This test shall be performed in accordance with method 1 of test Ta of IEC 60068-2-20. The terminations shall be examined for good tinning, as evidenced by free flowing of the solder with wetting of the terminations.

###### **Test B (surface mounted devices)**

This test shall be performed in accordance with test Td of IEC 60068-2-58. The immersion time shall be  $2\text{ s} \pm 0,2\text{ s}$  at a temperature of  $235^{\circ}\text{C} \pm 5^{\circ}\text{C}$ , unless otherwise specified in the detail specification. The terminations shall be examined for good wetting of the terminations.

#### 4.6.3.2 Resistance to soldering heat

##### Test A (lead terminations)

This test shall be performed in accordance with method 1A of test Tb of IEC 60068-2-20. The immersion time shall be  $5\text{ s} \pm 1\text{ s}$ , unless otherwise specified in the detail specification. A screen of thermally insulating material shall be used to prevent the component being heated by direct radiation from the solder bath. It shall also allow the immersion of the terminations up to a point 2 mm from the emergence of the terminations from the body, unless otherwise specified in the detail specification.

##### Test B (surface mounted devices)

This test shall be performed in accordance with test Td of IEC 60068-2-58. The immersion time shall be  $10\text{ s} \pm 1\text{ s}$ , at a temperature of  $260\text{ }^{\circ}\text{C} \pm 5\text{ }^{\circ}\text{C}$ , unless otherwise specified in the detail specification.

#### 4.6.4 Rapid change of temperature: severe shock by liquid immersion (non-destructive)

The test shall be performed in accordance with test Nc of IEC 60068-2-14. The units shall be subjected to one cycle in a downward direction from  $98\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$  to  $1\text{ }^{\circ}\text{C} \pm 1\text{ }^{\circ}\text{C}$  for 5 s.

#### 4.6.5 Rapid change of temperature: thermal shock in air (non-destructive)

The test shall be performed in accordance with test Na of IEC 60068-2-14.

For non-temperature-controlled crystal oscillators, the low and high test chamber temperatures shall be the extreme temperatures of the operating range stated in the detail specification. For temperature-controlled crystal oscillators, the low and high temperatures shall be  $-40\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$  and  $+85\text{ }^{\circ}\text{C} \pm 3\text{ }^{\circ}\text{C}$ , respectively, unless otherwise stated in the detail specification.

The crystal oscillators shall be maintained at each extreme of temperature for 30 min, unless otherwise specified in the detail specification.

The crystal oscillators shall be subjected to 10 complete thermal cycles and then exposed to standard atmospheric conditions for recovery for not less than 2 h.

#### 4.6.6 Bump (destructive)

The test shall be performed in accordance with test Eb of IEC 60068-2-29. The crystal oscillators shall be mounted or clamped as required by the detail specification. The three mutually perpendicular axes in which the bump is to be applied shall include:

- an axis parallel with the terminations;
- an axis parallel to the base of the crystal oscillator unit.

For surface mounted devices (SMD):

- an axis parallel with the terminal land plane;
- an axis perpendicular with the terminal land plane.

Unless otherwise specified, the combination of acceleration, duration and number of bumps shall be as specified in 2.3.2.

#### **4.6.7 Vibration (destructive)**

##### **4.6.7.1 Vibration, sinusoidal (oscillator not operating)**

The test shall be performed in accordance with test Fc of IEC 60068-2-6. The crystal oscillators shall be mounted or clamped as required by the detail specification. The three mutually perpendicular axes in which the acceleration is to be applied shall include:

- an axis parallel with the terminations;
- an axis parallel to the base of the crystal oscillator unit.

For surface mounted devices (SMD):

- an axis parallel with the terminal land plane;
- an axis perpendicular with the terminal land plane.

The detail specification shall state the acceleration spectral density (ASD), the frequency range and duration.

##### **4.6.7.2 Vibration, sinusoidal (oscillator operating)**

The test shall be as described in 4.6.7.1, except that, during the test, the oscillator shall be energized and electrical tests, as defined in the detail specification, shall be performed.

Unless otherwise stated, the combination of frequency range, vibration amplitude and duration of endurance for the above tests shall be as stated in 2.3.3.

##### **4.6.7.3 Random vibration (oscillator not operating)**

The test shall be performed in accordance with test Fdb of IEC 60068-2-36. The crystal oscillator shall be mounted or clamped as required by the detail specification. The three mutually perpendicular axes in which the acceleration is to be applied shall include:

- an axis parallel to the terminations;
- an axis parallel to the base of the crystal oscillator unit.

For surface mounted devices (SMD):

- an axis parallel with the terminal land plane;
- an axis perpendicular with the terminal land plane.

The detail specification shall state the acceleration spectral density (ASD), frequency range and duration.

##### **4.6.7.4 Random vibration (oscillator operating)**

The test shall be as described in 4.6.7.3, except that, during the test, the oscillator shall be energized and electrical tests, as defined in the detail specification, shall be performed.

#### **4.6.8 Shock (destructive)**

The test shall be performed in accordance with test Ea of IEC 60068-2-27. The crystal oscillators shall be mounted or clamped as required by the detail specification. The three mutually perpendicular axes in which the shock is to be applied shall include:

- an axis parallel with the terminations;
- an axis parallel to the base of the crystal oscillator unit.

For surface mounted devices (SMD):

- an axis parallel with the terminal land plane;
- an axis perpendicular with the terminal land plane.

The degree of severity shall be as stated in 2.3.4, unless otherwise stated in the detail specification.

#### **4.6.9 Free fall (destructive)**

The test shall be performed in accordance with procedure 1 of test Ed of IEC 60068-2-32. The crystal oscillator shall be suspended by its terminations at a height of 1 000 mm. The number of falls shall be two, unless otherwise stated in the detail specification.

#### **4.6.10 Acceleration, steady-state (non-destructive)**

##### **4.6.10.1 Acceleration, steady-state (oscillator not operating)**

The test shall be performed in accordance with test Ga of IEC 60068-2-7. The crystal oscillators shall be mounted or clamped as required by the detail specification. The procedure and severity shall be as stated in the detail specification.

##### **4.6.10.2 Acceleration, steady-state (oscillator operating)**

The test shall be as described in 4.6.10.1, except that, during the test, the oscillator shall be energized and electrical tests, as defined in the detail specification, shall be performed.

The procedure and severity shall be as stated in the detail specification.

#### **4.6.11 Acceleration – 2g tip over**

To be agreed upon by the customer and the supplier.

#### **4.6.12 Acoustic noise**

To be agreed upon by the customer and the supplier.

#### **4.6.13 Low air pressure (non-destructive)**

This test shall be performed in accordance with test M of IEC 60068-2-13. The procedure and severity shall be as stated in the detail specification.

#### **4.6.14 Dry heat (non-destructive)**

This test shall be performed in accordance with test Ba of IEC 60068-2-2. The conditioning shall be carried out at the upper temperature indicated by the climatic category, for a duration of 16 h, unless otherwise stated in the detail specification.

#### **4.6.15 Damp heat, cyclic (destructive)**

This test shall be performed in accordance with test Db, variant 1, of IEC 60068-2-30, at severity b) and 55 °C for six cycles.

#### 4.6.16 Cold (non-destructive)

This test shall be performed in accordance with test Aa of IEC 60068-2-1, at the lower temperature indicated by the climatic category, for a duration of 2 h, unless otherwise stated in the detail specification.

#### 4.6.17 Climatic sequence (destructive)

The tests and measurements shall be performed in the following order:

- dry heat see 4.6.14;
- damp heat, cyclic see 4.6.15  
(first cycle only);
- cold see 4.6.16;
- damp heat, cyclic see 4.6.15  
(remaining five cycles).

In the climatic sequence, an interval of not more than three days is permitted between any of these tests, except between damp heat cyclic (first cycle) and cold tests.

In such a case, the cold test shall follow immediately after the recovery period specified for the damp heat test.

#### 4.6.18 Damp heat, steady-state (destructive)

This test shall be performed in accordance with test Ca of IEC 60068-2-3, for 56 days, unless otherwise stated in the detail specification.

#### 4.6.19 Salt mist, cyclic (destructive)

This test shall be performed in accordance with test Kb of IEC 60068-2-52. Severity 1 shall be used, unless otherwise stated in the detail specification.

#### 4.6.20 Mould growth (non-destructive)

This test shall be performed in accordance with test J, variant 2, of IEC 60068-2-10.

**WARNING – This test can constitute a health hazard, therefore, special precautions should be observed (see annex A of IEC 60068-2-10).**

#### 4.6.21 Immersion in cleaning solvents (non-destructive)

This test is applicable to superficial markings only. To establish the permanence of marking, this test shall be performed in accordance with method 1 of test XA of IEC 60068-2-45. The detail specification shall prescribe the solvent, the temperature of the solvent, the rubbing material and its dimensions, and the force to be used.

The marking shall be legible.

#### 4.6.22 Radiation hardness

To be agreed upon by the customer and supplier.

#### 4.7 Endurance test procedure

#### 4.7.1 Ageing (non-destructive)

The oscillator units shall be maintained at a specified temperature for a continuous period of 30 days. During the period of the test, the control of temperature and the accuracy of frequency measurement shall be consistent with the accuracy of the maximum frequency variations specified. The oscillator units shall remain in the chamber throughout the duration of the test and shall be continually supplied with input power, unless otherwise specified.

The output frequency shall be measured at the end of the first 24 hours and at the end of the 30 day period. Additionally, at least four intermediate measurements shall be taken at intervals of not less than one day and not greater than five days. Measurements shall be carried out according to 4.5.4.

The performance requirements shall be expressed in terms of a maximum frequency change during the period of the test, or in terms of the slope of the frequency against time curve during the last five days of the test, based upon a minimum of three measurements.

Preferred conditions: SPXO and TCXO, the highest operating temperature specified; OCXO,  $+25^{\circ}\text{C} \pm 2^{\circ}\text{C}$ .

#### **4.7.2 Extended ageing (non-destructive)**

This test shall be carried out in accordance with 4.7.1, except that the continuous periods shall be 1 000 h, 2 000 h or 8 000 h, as prescribed in the detail specification, and shall be used for information purposes only.

Measurements shall be carried out according to 4.5.4, except that they shall be made at  $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$  or any other specified temperature.

#### **4.7.3 Power consumption ageing**

For sealed oven controlled quartz crystal oscillators the measurement of power consumption ageing rate shall be performed concurrently with the ageing test of 4.7.1.

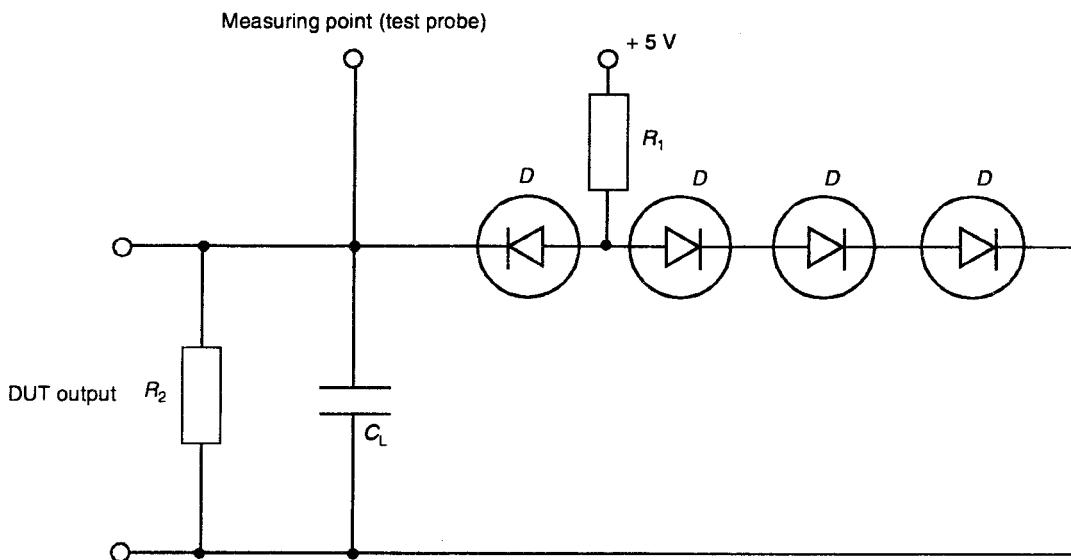
The test conditions and requirements of 4.7.1 shall apply.

## Annex A (normative)

### Load circuit for logic drive

#### A.1 TTL and Schottky

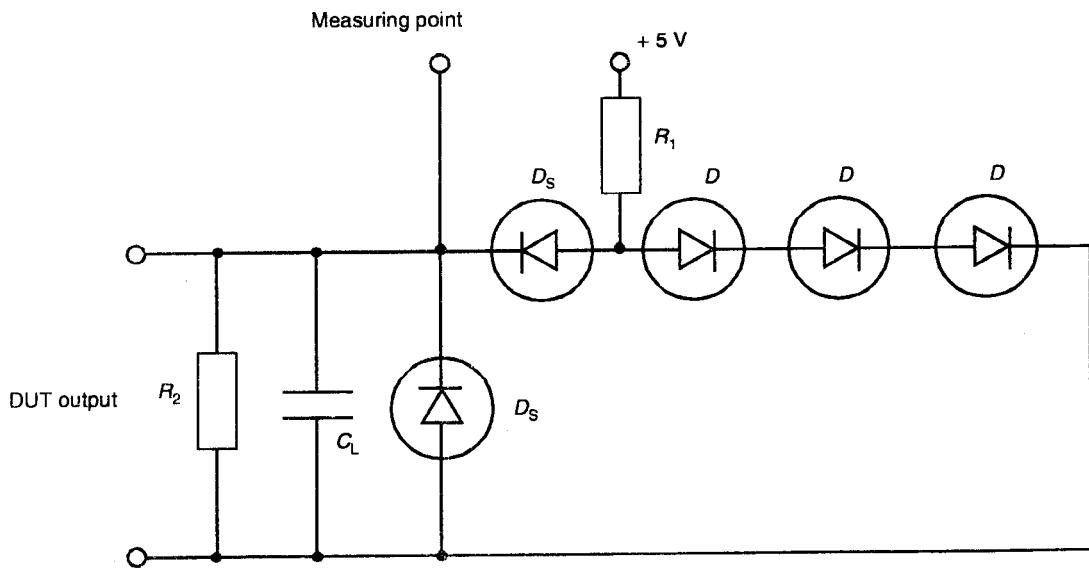
The test fixture for oscillators designed with logic drive circuits shall simulate the load conditions which the oscillator is required to drive. Preferred test circuits for TTL and Schottky logic are shown in figures A.1 and A.2, respectively.



NOTE – Standard TTL (54/74 series)

High speed TTL (54/74 series)

Figure A.1 – Circuit for TTL



NOTE – Schottky logic (54S/74S series)

Low power Schottky logic (54LS/74LS series)

**Figure A.2 – Circuit for Schottky logic**

Key to figures A.1 and A.2:

- diodes marked D shall be type 1N916 or 1N3064;
- diodes marked  $D_S$  shall be high speed Schottky type, for example 1S1993;
- values for  $R_1$  and  $R_2$  are dependent on the load requirement and may be calculated using the formulae:

$$R_1 = \frac{5 - (V_{OL} + V_D)}{n |I_{IL}|}$$

$$R_2 = \frac{V_{OH}}{n |I_{IH}|}$$

where

$n$  is the number of gates;

$V_{OL}$  is the oscillator low level output voltage;

$I_{IL}$  is the low level input current per gate;

$V_{OH}$  is the oscillator high level output voltage;

$I_{IH}$  is the high level input current per gate;

$V_D$  is the voltage drop across the diode.

NOTE –  $V_D = 0,65$  V for figure A.1 and  $V_D = 0,45$  V for figure A.2.

Values of these parameters for various TTL series for use in the above formulae are given in table A.1.

Values for  $C_L$  are also given. It should be noted that  $C_L$  includes the probe and fixture capacitance.

The oscillator output voltage limit requirements using the test circuits of figure A.1 and A.2 will normally be:

$V_{OH} = 2,4$  V min.

$V_{OL} = 0,5$  V max.

**Table A.1 – Values to be used when calculating  $R_1$  and  $R_2$**

TTL series	74	54	74H	54H	74L	54L	74LS	54LS	74S	54S
$V_{OH}$ (V)	2,4	2,4	2,4	2,4	2,4	2,4	2,7	2,7	2,7	2,7
$V_{OL}$ (V)	0,4	0,4	0,4	0,4	0,3	0,3	0,4	0,4	0,5	0,5
$I_{IH}$ ( $\mu$ A)	40	40	50	50	10	10	20	20	50	50
$I_{IL}$ (mA)	-1,6	-1,6	-2,0	-2,0	-0,18	-0,18	-0,4	-0,4	-2,0	-2,0
$C_L$ (pF)	15	15	25	25	50	50	15	15	15	15

The following information shall be specified in the detail specification:

$R_1$ ,  $R_2$ ,  $C_L$ ,  $V_{OH}$  and  $V_{OL}$ , together with the circuit to which reference is made.

NOTE – Satisfactory operation in a particular circuit should not be considered as an assurance that a specific crystal oscillator will operate satisfactorily with all types of TTL logic.

## A.2 CMOS

The test fixture for oscillators designed for CMOS logic circuits should simulate the load conditions which the oscillator is required to drive. The load circuit shall consist of a capacitance which shall be 10 pF times the number of gates being driven. The figure of 10 pF includes a 2,5 pF allowance for strays.

NOTE – Satisfactory operation under these conditions should not be considered as an assurance that a specific crystal oscillator will operate in a satisfactory manner in any CMOS logic circuit.

## A.3 ECL

Under consideration.

**Annex B**  
(informative)

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## BUREAU OF INDIAN STANDARDS

### Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110 002  
Telephones : 323 01 31, 323 33 75, 323 94 02

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( Common to all offices )

### Regional Offices :

Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg  
NEW DELHI 110 002

Telephone

{ 323 76 17  
323 38 41

Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Kankurgachi  
KOLKATA 700 054

{ 337 84 99, 337 85 61  
337 86 26, 337 91 20

Northern : SCO 335-336, Sector 34-A, CHANDIGARH 160 022

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Southern : C. I. T. Campus, IV Cross Road, CHENNAI 600 113

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